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THE OHIO JOURNAL OF SCIENCE

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AN ECOLOGICAL STUDY OF THE SPIDERS OF THE BEECH-MAPLE FOREST.*

FRANK R. ELLIOTT.

INTRODUCTION.

The members of the order Araneæ have been studied extensively in several sections of North America by a number of students of the group including Walckenaer, McCook, Emerton, R. V. Chamberlin, Banks, Petrunkevitch, Peckham, Barrows, Crosby, Bishop and others with the result that now new species of spiders are of little more frequent report than new species of insects in many of the orders.

Works of a non-taxonomic nature dealing with seasonal succession and abundance, migration, hibernation, quantitative relations etc. have had to do with the entire population or a rather large group (Adams 1915), (Holmquist 1926) in an association such as Prairie (Adams 1915), Coniferous forest (Sanderson and Shelford 1922), (Adams 1920), (Blake 1926) or Deciduous forest (Shelford 1912, 13) (Adams 1915) (Weese 1924), (Blake 1926).

The study here considered is that of the Beech-Maple forest and is limited to an intensive consideration of the Spiders. These are here discussed from two view points; Taxonomic, having to do with the species present in the beech-maple forest and Ecological, involving a discussion of the species present as to specificity for the habitat, hibernation, migration, annual and seasonal cycle, and various other ecological aspects.

An eighty acre Beech-Maple forest, known as Lewis Woods, located in extreme eastern Indiana, near Richmond, was selected as a restricted area for intensive observation and collection. This area is a rectangular tract 80 by 160 rods, heavily wooded with beech and sugar maple on the upland

*Contribution No. 96 from the Department of Zoology and Entomology, Ohio State University.

portion with admixture of some ash, and an occasional buckeye and linden on lower levels. This forest had not been pastured for thirty-five years and then only occasionally nor had any timber been removed from it during that time except the removal of a few beech trees over an area of about three acres near each end, about three years ago. This forest is the Beech-Sugar mesophytic forest typical of well drained physiographically mature soils (Sears 1926) and doubtless a typical primary association, and being unmodified by activity of man well represents a close approximation to primitive forest conditions. Its spider population is doubtless similarly typically representative.

Collecting was by beating branches and small trees, sweeping herbs and bushes, sifting leaves, humus and upper soil layer and the removal of bark and wood of dead trees, logs, woodpiles and stumps.

Collections and observations were made in other Beech-Maple forests in Indiana and Ohio with results which coincided with those obtained in the selected environment.

The account of the Spiders is given as follows: (a) The beech-maple forest as a habitat and the interrelation of the physical and biotic factors (b) species, genera, and families of spiders present (c) the distribution of the spiders in the beech-maple association (d) the annual and seasonal succession (e) migration and hibernation (f) the specificity of the species present for the association and (g) the representation of each species and the relation of the principal species to the total spider population.

I am very much indebted to Dr. W. M. Barrows of the Department of Zoology of Ohio State University for valuable suggestions, assistance in the determination of the species and the loan of literature.

The Beech-Maple Forest as a Habitat.

The beech-maple forest like that of the deciduous forest in general presents a well stratified habitat with more uniform conditions for any period of the year than those in other associations such as the low arctic tundra, prairie, heath, etc. This is in part due to the absence of alpine conditions and in large measure to the influence of the forest cover itself. The marked physical feature is the constancy and sharpness of the strata, this being correlated with and primarily caused by

stratification of plant societies. The principal strata are Forest floor, Herb, Shrub and Bush and the Forest cover.

The forest floor is a level of low but constant temperature, high moisture, minimum evaporation, scant light, rather constant population except in winter when increased by migrants. The predominant animals are those suited to considerable moisture, fairly low summer temperature and minimum light.

From the forest floor to the herb stratum occurs the steepest gradient in the series for the physical factors. Animals going from the ground floor to the herb stratum undergo pronounced changes in the physical environment. The population of this stratum is larger and more varied than that of any other stratum.

Shrub and Bush and Forest cover present differences of the same character as those between forest floor and herb strata but of much less magnitude and of less decisive character.

Examination of the population of the forest shows that it exhibits rather definite divisions into stratal societies. A further study (Weese) brings out an existing correlation between the physical and biotic differences of the successive strata. These two forces are of different importance at different periods of the annual cycle, the physical factors becoming markedly of greater importance at seasonal periods. This is very clearly evidenced in the beech-maple forest in the case of spiders by changing distribution in the autumn and spring.

During spring, summer and fall the animal population of the forest falls into stratal societies which are in general in agreement with the stratification of physical factors and vegetation. This would seem to be of direct value to the plant eating forms, but since even they respond to the physical factors by stratum to stratum migration, and as stratification occurs also among such animals as spiders which possess no relations with the vegetation it would seem that the physical factors are important and decisive (Blake 1926). A considerable number of species of spiders habitually pass between herb and shrub strata while a much smaller number divide their activity between ground and herb strata. The tendency seems to be for animals to make traverse only between strata which are separated by moderate gradients.

Weese (1924) gives evidence that the lower temperature fluctuations of fall serves as a stimulus causing beetles to migrate first into the interior of the forest then downward into the lower strata for hibernation. The downward migra-

tion of both young and adults of many herb and shrub inhabitating spiders is a distinctive characteristic of the group, more than half of the species here found doing so, and is in all probability a definite response primarily to changing temperatures. Vertical shifting, community stratification and other distribution of spiders though of less extreme character are in all probability largely gradational responses to changing biotic and physical conditions.

The Spiders Occurring in Beech-Maple Forest.

The name given to each spider is that listed in the Synonymic Index-Catalogue of Spiders of North, Central and South America (Petrunkevitch). The Synonomy is also largely based on the same. No attempt is made to give a complete synonomy but merely to list the principal other names by which a spider has been described by leading Arachnologists, principally Blackwall, Chamberlin, Emerton, Hentz, Keyserling, McCook, Peckham, Simon, and Walckenaer, to the end that it may best serve the needs of those having recourse to any of these works. In most cases the name listed is that by which the individual is best known. In some instances, however, a spider is best known by some synonym and will be most frequently described by American students under such. Confusion resulting from the nomenclature given however is compensated by advantages accruing from adherence to the rule of priority. The arrangement of the families and genera is that given in Systema Aranearum, by the same author. The species are for convenience numbered from one to ninety-nine.

Family **Dysderidæ.**

1. *Ariadne bicolor* Hentz. Same Emerton-Simon; *Pylarus bicolor* and *pumulis* Hentz.

Family **Amaurobidæ.**

2. *Amaurobius americana* Emerton. *Titanoeca americana* Emerton-Banks; *Titanoeca brunnea* Emerton.
3. *Amaurobius bennetti* Blackwall. Same Banks; *Ciniflo benneti* Blackwall; *A. sylvestris* Emerton-Simon.

Family **Agelenidæ.**

4. *Agelena naevia* Walckenaer. Same Hentz-Emerton; *Agelena peninsulana* C. Koch; *Agelena potteri* Blackwall; *Agelena americana* Keyserling.
5. *Cicurina arcuta* Keyserling. Same Simon; *Cicurina complicata* Emerton.
6. *Cicurina brevis* Emerton. Same Banks; *Tegenaria brevis* Emerton; *Cicurina creber* Banks.
7. *Cicurina pallida* Keyserling. Same Emerton.
8. *Coelotes hybridus* Emerton.

9. *Coelotes longitarsus* Emerton. *Coelotes gnavus* Banks.
10. *Coelotes montanus* Emerton.
11. *Coras medicinalis* Hentz. Same Emerton-Simon. *Teneraria medicinalis* Hentz; *Coelotes medicinalis* Emerton; *Coelotes urbanus* Keyserling.
12. *Hahnia agilis* Kerserling. *Hahnia bimaculata* Emerton.
13. *Hahnia cinerea* Emerton.
14. *Hahnia radula* Emerton. Same Simon.

Family **Pisaurinidæ.**

15. *Pisaurina mira* Walckenaer. Same Montgomery; *Dolomedes mirus* and *virgatus* Walckanaer; *Micrommata undata, serrata, caroliensis* and *marmorata* Hentz; *Pisaurina undata* Banks; *Ocyale undata* Emerton-Montgomery; *Dolomedes binotatur* C. Koch.
16. *Dolomedes fontanus* Emerton. Same Montgomery; *Dolomedes tenebrosus* Emerton-Hentz.

Family **Lycosidæ.**

17. *Allocosa funerea* Hentz. Same Chamberlin; *Lycosa funerea* Hentz; *Lycosa* and *Trochosa sublata* Montgomery.
18. *Lycosa gulosa* Walckenaer. Same Chamberlin; *Lycosa kochii* Emerton; *Lycosa purcelli, nigraurata, euepigyrata* and *insopita* Montgomery; *Trochosa purcelli* Montgomery; *Tarentula pulchra* Keyserling; *Lycosa pulchra* Chamberlin.
19. *Lycosa rabida* Walckenaer. Same Banks; *Lycosa scutulata* Hentz-Emerton-Montgomery-Chamberlin.
20. *Schizocosa crassipes* Walckenaer. Same Petrunkevitch; *Lycosa crassipes* Walckenaer; *Lycosa ocreata* Hentz-Keyserling-Emerton-Chamberlin; *Lycosa rufa* Kerserling; *Lycosa stonei* Montgomery; *Pardosa solivaga* Montgomery.
21. *Pirata febriculosa* Becker. *Lycosa febriculosa* Becker-Chamberlin; *Lycosa wacondana* Scheffer; *Pirata sedentarius* Montgomery.

Family **Dictynidæ.**

22. *Dictyna foliacea* Hentz. Same Banks; *Theridium foliaceum* Hentz; *Theridium roscidum* Hentz; *Theridion hypophyllum* Fitch; *Dictyna volupis* Keyserling-Emerton; *Dictyna dubia* Banks.
23. *Dictyna minuta* Emerton.
24. *Dictyna sublata* Hentz. Same Banks; *Theridion sublatum* and *morologum* Hentz; *Dictyna sedentaria* and *foliata* Keyserling; *Dictyna muraria* Emerton.
25. *Lathys foxii* Marx. Same Banks-Simon; *Prodalia foxii* Marx.
26. *Lathys pallida* Emerton. Trans. Conn. Acad. Sci., Vol. IX, 1894, new.

Family **Theridiidæ.**

27. *Pedanostethus pumulus* Emerton. Supplement New Eng. Spiders, Jan., 1909, Vol. 14, p. 183. Described as new.
28. *Crustulina guttata* Wider. Same Simon; *Theridion guttata* Wider; *Steatoda guttata* Emerton; *Crustulina sticta* Keyserling.
29. *Steatoda borealis* Emerton. Same Keyserling; *Theridion borealis* Hentz.
30. *Euryopis funebris* Hentz. Same Emerton-Keyserling-Simon-Banks; *Theridion funebre* Hentz.
31. *Theridion differens* Emerton. Same Keyserling.
32. *Theridion frondeum* Hentz. Same Emerton-Keyserling-Simon-Cambridge.
33. *Theridion pennsylvanicum* Emerton. Bulletin Am. Mus. Nat. Hist., Vol. XXXII, New and Rare Spiders Fifty Miles of New York.
34. *Theridula opulenta* Walckenaer. Same Simon-Cambridge-Hentz; *Theridula sphaerula* Emerton-Keyserling; *Theridion sphaerulum* Hentz; *Theridion gonygaster* Simon; *Theridula triangularis, quinqueguttata* and *quadripunctata* Keyserling; *Theridion ventillaris* Keyserling.

Family **Linyphiidæ.**

35. *Bathyphantes micraria* Emerton. Same Banks.
36. *Bathyphantes nigrinus* Westring. Same Simon; *Linyphia nigrina* Westring-Emerton; *Linyphia pulla* Blackwall; *Diplostyla nigrina* Emerton.

37. *Bathyphantes zebra* Emerton. Same Banks.
38. *Linyphia clathrata* Sundevall. Same Emerton-Simon; *Linyphis multiguttata* Ruess; *Linyphia luctuosa* C. Koch; *Nereine marginata* Blackwall; *Frontina clathrata* Keyserling.
39. *Linyphia conferta* Hentz. nec *L. conferta* Banks; nec *Floronia conferta* Banks.
40. *Linyphia marginata* Emerton. Same C. Koch-Simon-Keyserling; *Linyphia triangularis* Walckenaer-Blackwall; *Linyphia marmorata* Hentz.
41. *Linyphia phrygiana* C. Koch. Same Emerton-Simon-Keyserling; *Linyphia costata* Hentz.
42. *Microneta cornupalpis* Cambridge. Same Emerton-Banks-Simon; *Erigone cornupalpis* Cambridge.
43. *Ceraticelus minutus* Emerton. Same Crosby; *Ceratinella minuta* Banks-Emerton.
44. *Ceratinella brunnea* Emerton. Same Crosby; *Ceraticelus brunnea* Simon.
45. *Gongylidiellum pallidum* Emerton. Same Crosby; *Tmeticus pallidus* Emerton; *Erigone pallescens* Marx.
46. *Oedothorax montiferus* Emerton. Same Crosby; *Lophocarenum montiferum* Emerton. *Nereine montifera* Simon.
47. *Oedothorax platyrhinus* Crosby. See Journal New York Ent. Soc., Vol. XXXV, June, 1927—C. R. Crosby and Sherman C. Bishop.
48. *Oedothorax probatus* Cambridge. Same Crosby; *Erigone probata* Cambridge-Keyserling; *Tmeticus probatus* Emerton.
49. *Prosopotheca minuta* Emerton. Same Crosby-Simon; *Cornicularia minuta* Emerton; *Erigone paullula* Marx.
50. *Tmeticus aestivalis* Emerton. Trans. Conn. Acad. Sci., Vol. 16, 1911. New Spiders New England. Described as new.
51. *Ceratinopsis interpres* Cambridge. Same Emerton-Crosby; *Erigone interpres* Cambridge-Keyserling; *Notionelli interpres* Banks.
52. *Diplocephalus exiguus* Banks. Same Crosby; *Lophocarenum exiguum* Banks.
53. *Trachelocamptus rostratus* Emerton. Same Simon-Crosby. *Lophocarenum rostatum* Emerton.

Family **Uloboridæ.**

54. *Uloborus americana* Walckenaer. Same Cambridge; *Uloborus plumipis* Lucas-Emerton-Simon-McCook; *Uloborus villosus* Keyserling; *Phillyra manneata* and *riparia* Hentz.
55. *Hyptiotes cavatus* Hentz. Same Emerton-Simon-McCook; *Cyllopodia* Hentz; *Hyptiotes americanus* Wilder.

Family **Argyropidæ.**

56. *Acacesia foliata* Hentz. Same Simon-F. Cambridge; *Epeira foliata* Emerton-Hentz-McCook; *Epeira folifera* Marx.
57. *Araneus angulatus* Clerck. *Araneus virgatus* Clerck; *Epeira angulata* C. Koch-Simon-Emerton-McCook-Keyserling; *Epeira bicentenaria* McCook.
58. *Araneus arabesca* Wlackenaer. *Epeira arabesca* Walckenaer-McCook. *Epeira mutabilis* Walckenaer; *Epeira trivittata* Keyserling-Emerton; *Neoscona arabesca* F. Cambridge.
59. *Araneus arenatus* Walckenaer. *Epeira verrucosa* Hentz-Emerton. *Verrucosa arenata* McCook-F. Cambridge; *Mahadeva verrucosa* and *reticulata* Keyserling.
60. *Areneus ectypus* Walckenaer. *Epeira infumata* Hentz-Emerton. *Wixia ectypa* Keyserling-McCook; *Wicia infumata* Banks; *Epeira ectypa* Walckenaer-Keyserling.
61. *Araneus marmoreus* Clerck. *Araneus gigas conspicellata* Comstock; *Epeira insularis* Hentz-Keyserling-Emerton; *Epeira marmorea* C. Koch-Simon-Emerton-McCook; *Epeira scalaris* Walckenaer-Blackwall; *Epeira conspicellata* McCook-Walckenaer; *Epeira obesa* Hentz.
62. *Eustala anastera* Walckenaer. Same Simon-F. Cambridge; *Epeira bombicinaria* Hentz; *Epeira prompta* Hentz; *Epeira parvula* Emerton-Keyserling; *Epeira anastera* McCook.
63. *Mangora gibberosa* Hentz. *Epeira gibberosa* Hentz-Emerton-Keyserling; *Abbotia gibberosa* McCook; *Mangora gibberosa* Simon.

64. *Ordgarius bisaccatus* Emerton. Same Keyserling-McCook; *Glyptocranium bisaccatum* Emerton; *Epeira multilineata* Atkinson; *Cyrtarachne bisaccatum* Emerton.
65. *Leucauge venusta* Walckenaer. Same F. Cambridge; *Epeira venusta* Walckenaer; *Epeira hortorum* Hentz; *Argyroepeira hortorum* Emerton-Keyserling-McCook-Simon. *Tetragnatha quinquelineata* Keyserling; *Linyphia aurulenta* Walckenaer-C. Koch.
66. *Tetragnatha laboriosa* Hentz. Same Keyserling-Emerton-Banks-McCook; *Tetragnatha fluviatilis* Keyserling; *Tetragnatha illinoioensis* Keyserling.
67. *Micrathena gracilis* Walckenaer. Same, F. Cambridge-Simon; *Plectana gracilis* Walckenaer; *Acrosoma matronale* C. Koch; *Epeira rugosa* Hentz; *Acrosoma rugosa* Emerton; *Acrosoma gracilis* McCook; *Micrathena matronalis* McCook.
68. *Micrathena sagittata* Walckenaer. Same, Simon-F. Cambridge; *Plectana sagittata* Walckenaer; *Epeira spinea* Hentz; *Acrosoma bovinum* Thorell; *Acrosoma spinea* Emerton; *Acrosoma sagittata* McCook.

Family **Mimetidæ.**

69. *Ero furcatus* Villers. Same Simon-Keyserling; *Aranea furcata* Villers-Simon; *Ero variegata* C. Koch; *Theridion variegatum* Walckenaer-Blackwall; *Theridion leoninum* Hentz; *Ero thoracica* Thorell-Emerton.

Family **Drassidæ.**

70. *Herpyllus vasifer* Walckenaer. Same Simon; *Drassus vasifer* Walckenaer-Blackwall; *Herpyllus ecclesiasticus* Hentz; *Prosthesima propinqua* Keyserling; *Prosthesima ecclesiasticus* Emerton.
71. *Nodocion* sp.
72. *Sergiolus variegatus* Hentz. Same Emerton-Simon; *Herpyllus variegatus* Hentz; *Poecilochroa variegata* Emerton.
73. *Zelotes ater* Hentz. *Herpyllus ater* Hentz; *Prosthesima melancholica* Thorell; *Prosthesima funesta* Keyserling; *P. atra* Emerton; *Melanophora atra* Simon.

Family **Thomisidæ.**

74. *Philodromus minutus* Banks. *Philodromus brevis* Emerton; *Philodromus minusculus* Banks.
75. *Misumenops asperatus* Hentz. Same Emerton-Banks; *Misumena rosea* Keyserling-Banks; *misumena foliata* Banks; *Misumena placida* Banks; *Thomisus asperatus* Hentz.
76. *Misumenops oblongus* Keyserling. *Misumena oblonga* Keyserling-Emerton; *Misumessus oblongus* Banks.
77. *Oxyptilus monroensis* Keyserling. Same Banks.
78. *Tmarus* sp.? Probably *angulatus* Walckenaer; *Tmarus caudatus* Emerton-Keyserling; *Tmarus rubromaculatus* Keyserling; *Thomisus caudatus* Hentz.
79. *Xysticus ferox* Hentz. Same Banks; *Xysticus stomachosus* Keyserling-Emerton; *Thomisus ferox* Hentz.
80. *Xysticus fraternis* Banks. (Spiders of Long Island).
81. *Xysticus nervosus* Banks. Same Emerton.

Family **Clubionidæ.**

82. *Clubiona obesa* Hentz. Same Banks. *Clubiona crassipalpis* Keyserling-Banks-Emerton; *Clubiona mixta* Emerton.
83. *Clubiona pallens* Hentz. *Clubiona excepta* L. Koch-Emerton.
84. *Anyphaena pectorosa* L. Koch. *Anyphaena calcarata* Simon-Emerton; *Gayenna calcarata* Banks.
85. *Anyphaena saltabunda* Hentz. Same Emerton-Simon; *Clubiona saltabunda* Hentz.
86. *Phrurolithus alarius* Hentz. *Phrurolithus borealis* Emerton, Trans. Conn. Acad. Sci. 'II; *Herpyllus alarius* Hentz; *Phrurolithus palustris* Banks, in Spiders Cayuga Lake Basin, '92.

87. *Phrurolithus palustris* Banks. *Phrurolithus borealis* Emerton. See Notes on the Spiders of Southeastern United States by S. C. Bishop and C. R. Crosby, Journal Elisha Mitchell Scientific Society, Vol. 41, Nos. 3 and 4, April, 1926.
88. *Phrurolithus similis* Banks. Spiders Long Island.
89. *Trachelas tranquillus* Hentz; *Trachelas ruber* Keyserling-Emerton-Simon; *Clubiona tranquilla* Hentz-Banks; *Agelena plumbea* Hentz.
90. *Castaneria cingulata* C. Koch. *Castaneria bivittata* Keyserling; *Goetrecha bivittata* Emerton; *Thargalia bivittata* Banks; *Herpyllus zonarius* Hentz; *Spargassus cingulatus* Walckenaer; *Corinna cingulata* C. Koch.
91. *Castaneria longipalpus* Hentz. Same Banks; *Castaneria pinnata* Bryant; *Herpyllus longipalpus* Hentz; *Thargalia longipalpus, perplexa* and *pinnata* Banks; *Geotrecha pinnata* Emerton.

Family **Attidæ.**

92. *Synemosyna formica* Hentz. Same Emerton-Simon-Peckham; *Janus gibberosa* C. Koch.
93. *Maevia vittata.* Same Emerton-Simon-Peckham; *Attus vittatus* Hentz; *Attus niger* Hentz; *Plexippus undatus* C. Koch; *Maevia annulipes* C. Koch; *Astia vittata* Peckham.
94. *Habrocestum pulex* Hentz. Same Simon-Peckham; *Saitis pulex* Emerton-Peckham; *Saitis x-notata* Keyserling; *Cyrba pulex* Keyserling; *Attus pulex* Hentz; *Euophrys offuscata* C. Koch.
95. *Dendryphantes (Phidippus) audax* Hentz; *Attus audax* Hentz; *Attus tripunctatus* Hentz-Peckham; *Phidippus tripunctatus* Emerton; *Phidippus audax* Peckham; *Phidippus dubiosus* C. Koch.
96. *Dendryphantes capitatus* Hentz. Same Peckham; *Attus capitatus, hebes, parvus* and *octavus* Hentz; *Dendryphantes aestivalis* Emerton; *Dendryphantes insignis, ornatus* and *exiguus* Banks; *Dendryphantes octavus* Simon.
97. *Dendryphantes (Phidippus) clarus* Keyserling. *Phidippus insolens* Peckham; *Phidippus multiformis* Emerton-Peckham; *Phidippus minutus* and *princeps* Banks; *Phidippus clarus* Peckham.
98. *Icius hartii* Emerton. Same Banks-Peckham.
99. *Neon nelli* Peckham. Same Emerton-Simon; *Icius obliquus* Banks.

Distribution of the Spiders in the Association.

With the advent of spring and the first emergence of vegetation above the forest floor there is a marked increase in the activity of the spiders. As the season advances there is evidenced a pronounced different distribution of the species which becomes more and more marked. A number of the young and adults of species that have been present throughout the winter and newly hatched young of other species remain in the ground floor. Many of the species however definitely leave the forest floor not to reenter it again until the approach of winter.

The upward migration with most species extends but a few feet, the spiders being distributed on the low herbage, vines and shrubs. A few of the species however go well up into the trees. This is especially true of Araneus ectypa, Hyptiotes cavatus, Micrathena sagittata, Araneus arenatus, Philodromus minutus and Ordgarius bisaccatus. No attempt

was made to study carefully the forest cover to determine the number and kinds of spiders present in the same. Three groups only have been considered, Ground floor forms, Ground-Vegetation forms and Vegetation forms.

In Beech-Maple forest the separation of the vegetation into Herb stratum and Shrub stratum with reference to spiders cannot well be made as has been done in Elm-Maple (Weese) for the animal population in general. Almost without exception spiders thought to be of the herb stratum were found frequently in the shrub stratum. In addition all of the species listed as shrub forms for Elm-Maple (Weese) were in beech-maple found repeatedly in both shrub and herb stratum. In beech-maple forest differences in the physical factors, light, evaporation, humidity, temperature, etc. of the herb and shrub strata are apparently not great enough to bring about a stratification of the spider community.

The distribution of beech-maple spiders is here presented. The following forms were not listed in the groups, Allocosa funerea, a typical grassland form; Bathyphantes nigrinum, a typical grassland spider; Herpyllus vasifer, lives under bark; Ordgarius bisaccatus, a tree form; and Trachelas tranquillas, more typically a transitional or field form. The remaining species are as follows.

I. Ground Stratum Forms.

Forest floor spiders inhabiting leaves, humus and upper soil layer throughout the year.

Amaurobius americana
Amaurobius bennetti
Ariadne bicolor
Bathyphantes zebra
Castaneria cingulata
Castaneria longipalpis
Ceratinella brunnea
Ceraticelus minutus
Cicurina arcuata
Cicurina brevis
Cicurina pallida
Coelotes hybridus
Coelotes longitarsus
Coelotes montanus
Coras medicinalis
Crustulina guttata
Diplocephalus exiguus
Ero furcatus
Gongylidiellum pallidum
Hahnia agilis
Hahnia cinerea
Hahnia radula
Lathys foxii
Lathys sp. (*pallida?*)
Neon nellii
Nodocion sp.
Oedothorax platyrhinus
Oedothorax montiferus
Oedothorax probatus
Oxyptila monroensis
Pedanostethus pumulus
Phrurolithus alarius
Phrurolithus palustris
Phrurolithus similis
Prosopotheca minuta
Schizocosa crassipes
Tmeticus aestivalis
Trachelocamptus rostratus
Xysticus ferox
Xysticus fraternus
Zelotes ater

II. Ground-Herb-Shrub Forms.

Agelena naevia
Anyphaena saltabunda
Clubiona obesa
Clubiona pallens
Dendryphantes capitatus
Dendryphantes (Phid.) audax
Dendryphantes (Phid.) clarus
Dictyna foliacea
Dictyna minuta
Dictyna sublata
Dolomedes fontanus
Habrocestum pulex
Linyphia clathrata
Lycosa gulosa
Lycosa rabida
Maevia vittata
Micronetа cornupalpis
Pisaurina mira
Pirata febriculosa
Sergiolus variegatus
Synemosyna formica
Xysticus nervosus

III. Herb-Shrub Forms.

Acacesia foliata
Araneus angulatus
Araneus arenatus
Araneus ectypus
Araneus marmoreus
Bathyphantes micraria
Bathyphantes nigrinum
Ceratinopsis interpres
Euryopis funebris
Eustala anastera
Hyptiotes cavatus
Icius hartii
Leucauge venusta
Linyphia marginata
Linyphia conferta
Linyphia phrygiana
Mangora gibberosa
Micrathena gracilis
Micrathena sagittata
Misumenops asperatus
Philodromus minutus
Steatoda borealis
Tetragnatha laboriosa
Theridion differens
Theridion frondeum
Theridion pennsylvanicum
Theridula opulenta
Tmarus sp. (*caudatus?*)
Uloborus americana

The Annual and Seasonal Succession.

The annual cycle of beech-maple spiders in their relation to the physical factors of the habitat, distribution in the forest and the dominants of the region is best understood in terms of its seasonal divisions, spring, summer, autumn and winter.

The Spring Period extends from about March 1 to June 1. The first portion is characterized by the absence of green vegetation and by rapidly rising temperature of both air and soil together with considerable rainfall. The forest as a habitat is still limited to the ground floor stratum. The spider community is practically restricted to this except such forms as on warmer days move about on the leaves and dead vegetation near the ground. The principal spiders present are Amaurobius bennetti, Gongylidiellum pallidum, Oedothorax probatus, Coelotes longitarsus, Phrurolithus palustris and Tmeticus aestivalis. The last three are the dominant species. It is interesting to note that all of the principal species are typical ground floor inhabitants.

The second portion is characterized by a well developed plant society of herb strata, advanced leaf condition of the

shrubs and appearance of green on the trees. Temperatures are much higher, rainfall less and insect life is abundant. The habitat now consists of two strata, ground floor and herb-shrub. The principal spiders of the ground floor are Amaurobius bennetti, Ariadne bicolor, Coelotes hybridus, Xysticus fraternus, Tmeticus aestivalis, Coelotes longitarsus, Phrurolithus palustris, Gongylidiellum pallidum and Hahnia agilis. The last four being the dominant forms. The principal species of Shrub-Herb Strata are Dendryphantes capitatus, Leucauge venusta, Ceratinopsis interpres and Theridion frondeum. The last two are the dominant forms.

The Summer Period extends from about June 1 to September 1. The first or aestival portion is characterized by rising temperature, increased evaporation and less light. The forest cover is well foliated and serves as shade. The dominant ground floor spiders are Agelena naevia, Phrurolithus alarius and Crustulina guttata. The principal species of the herb strata are Linyphia clathrata, Dendryphantes capitatus, Dictyna minuta, Leucauge venusta, Araneus marmoreus, Theridion frondeum and Micrathena sagittata. The last four are the dominant forms. Micrathena sagittata easily exceeds other forms being taken with almost every sweep of the net.

The later or serotinal period is characterized by a reversal of the aestival changes. The principal ground forms are Anyphaena saltabunda, Cicurina arcuata, Oedothorax probatus, Agelena naevia and Gongylidiellum pallidum. The last two are easily the dominant forms. Species of the Herb-Shrub stratum are Araneus marmoreus, Pisaurina mira, Leucauge venusta, Araneus arenatus and Mangora gibberosa. The last three are dominant forms, Mangora gibberosa far exceeding any other form. Numerous webs of Araneus arenatus with adult females are present. Micrathena sagittata so abundant in the late aestival is now limited to a small number of adults.

The Autmnal or Fall Period begins about September 1. This is characterized by a decline in temperature and some increase in light through reduction of shade from the forest cover. The forest floor is rapidly being covered anew with dead leaves which lie loosely upon the ground and are changing position frequently. This is rich in spiders from the herb and shrub strata as well as those that have migrated from the forest border. The herb-shrub stratum is still present but is rapidly

giving way to changing physical factors and assuming less importance. The principal species of the ground floor are Xysticus fraternus, Phrurolithus palustris, Amaurobius bennetti, Gongylidiellum pallidum, Oedothorax probatus and Anyphaena saltabunda. The last two are easily the dominant forms. The principal species of the early part of Autumn are Mangora gibberosa, Theridion frondeum, Dendryphantes capitatus, Pisaurina mira and Dictyna foliacea. The last two are dominants.

The Winter Period is characterized by the reduction of the habitat to a single stratum. Low temperature, increased light and more pronounced wind effects are present, a condition closely paralleling that of the tundra is now present. The principal ground floor forms are Anyphaena saltabunda, Linyphia clathrata, Phrurolithus palustris, Coras medicinalis, Amaurobius bennetti, and Xysticus fraternus. The last three are dominants. Physical factors now almost completely dominate biotic except for brief periods of rising temperature.

The Spider population of the beech-maple forest shows two distinct high peaks, one in late spring about May 1 and another in late summer about August 1. The late summer peak is not caused to an appreciable extent by the appearance of new species but is the result of the two distinct phases of spider life. In August the young from the spring adults have begun to appear and are at the peak within a few days. July is the worst month for collecting. Many of the adults of spring have disappeared, especially the males.

The dominant species of the Seasons follow:

Ground Floor Stratum		Herb-Shrub Stratum
	SPRING.	
Prevernal period:		
Hahnia agilis		None
Gongylidiellum pallidum		
Phrurolithus palustris		
Coelotes longitarsus		
Vernal period:		
Hahnia agilis		*Ceratinopsis interpres*
Gongylidiellum pallidum		*Theridion frondeum*
Phrurolithis palustris		
Coelotes longitarsus		
	SUMMER.	
Aestival period:		
Agelena naevia		*Micrathena sagittata*
Phrurolithus alarius		*Theridion frondeum*
Crustulina guttata		*Araneus marmoreus*
		Lecauge venusta

Serotinal period:		
Agelena naevia		*Mangora gibberosa*
Gongylidiellum pallidum		*Araenus arenatus*
		Leucauge venusta
	AUTUMN.	
Anyphaena saltabunda		*Dictyna foliacea*
Oedothorax probatus		*Pisaurina mira*
	WINTER.	
Amaurobius bennetti		None
Phrurolithus alarius		
Xysticus fraternus		

Migration and Hibernation.

A few spiders hibernate in special situations, as, Herpyllus vasifer, under bark; Amaurobius bennetti, in logs and stumps; Dolomedes fontanus, in piles of wood and under bark of logs.

Most of the spiders, however, winter over in the leaves, humus and soil strata. The general migration begins about the middle of September and progresses according to temperature, frost conditions and duration of the herbage near the forest floor. By the middle of October the weeds and herbage are for the most part dead and few spiders are found on the same except near the ground.

Certain of the spiders migrate at once into the deeper strata and are not seen again until the emergence in the spring. Other species remain in the forest floor a considerable time and migrate downward just before freezing. Very warm periods call up from the deeper hibernation these forms not found during winter weather. Upon the resumption of cold they disappear returning to the region lower in the ground, probably below the frost line. Still other species remain comparatively near the surface in the top soil or leaf stratum. Among these are many young and adults that live throughout the winter as such, together with adults of species that die in the late fall; the egg sac containing the winter stage, either eggs or young as the case may be. These seem to consist of species that are able to tolerate freezing with very little harm.

The results of the experimental study of the physical factors and distribution of the total animal population in Elm-Maple forest (Weese 1924) shows little correlation between this winter distribution and the atmospheric humidity. Changes in the population of hibernating animals are more probably influenced by the changing temperature than by any other physical factor. Population apices apparently coincide with

temperature changes. These described temperature relations exist with reference to the distribution of spiders. Apparently however the upward and downward migration, though unrelated to atmospheric humidity is to a considerable extent dependent in addition to temperature upon the amount of water present in the forest floor. In both cold and warm dry weather many spiders are well down in the upper soil level. Following heavy rains these migrate upward into the less moist leaf layer. This migration is repeated several times during the winter occurring with each melting of the snow. During March and April this vertical shifting is quite in evidence during alternate freezing and thawing and wet and dry periods.

In the hibernation period biotic influences are at their lowest. Many of the spiders are in a quiescent or dormant condition except during the rising temperature periods referred to. In these periods there is little evidence of predatory activity on the part of spiders.

It has not been possible to determine with certainty the hibernation stage for all the species. Time has not permitted the collection of egg sacs and examination of these for young or the keeping of them until hatching for the determination of the species. The hibernation stage of many of the species rests upon the collection of spiders made in December, January and February. The finding of a single individual does not necessarily determine the nature of the winter stage. Such an occurrence may be accidental. The presence of three or more individuals, especially if found on different occasions is taken to be the hibernation stage. The over-wintering stage of all the species is considered. The determination of 73 of these has been made. The species are grouped under three headings, spiders that hibernate in the immature or adult form, those that winter over in the egg sac either as young or eggs, and species with the hibernation stage undetermined.

Spiders That Hibernate in Immature or Adult Form.

Amaurobinus bennetti
Anyphaena saltabunda
Araneus arabesca
Ariadne bicolor
Bathyphantes nigrinum
Bathyphantes zebra
Castaneria cingulata
Ceraticelus minutus
Ceratinopsis interpres
Cicurina brevis
Cicurina arcuata
Hahnia cinerea
Hahnia radula
Herpyllus vasifer
Hyptiotes cavatus
Lathys foxii
Lathys pallida
Linyphia clathrata
Linyphia phrygiana
Lycosa rabida
Maevia vittata
Microneta cornupalpis

Cicurina pallida
Clubiona obesa
Clubiona pallens
Coelotes hybridus
Coelotes longitarsus
Coelotes montanus
Coras medicinalis
Crustulina guttata
Dendryphantes capitatus
Dendryphantes (Phid.) audax
Dendryphantes (Phid.) clarus
Dictyna foliacea
Dictyna minuta
Dictyna sublata
Diplocephalus exiguus
Dolomedes fontanus
Ero furcatus
Euryopis funebris
Eustala anastera
Gongylidiellum pallidum
Habrocestum pulex
Hahnia agilis
Misumenops asperatus
Neon nellii
Nodocion sp.
Oedothorax probatus
Oedothorax montiferus
Oedothorax platyrhinus
Phrurolithus alarius
Phrurolithus palustris
Pisaurina mira
Schizocosa crassipes
Sergiolus variegatus
Steatoda borealis
Tetragnatha laboriosa
Theridion frondeum
Tmeticus aestivalis
Trachelas tranquillas
Trachelocamptus rostratus
Uloborus americana
Xysticus ferox
Xysticus fraternus
Zelotes ater

Species That Winter Over in the Egg Sac as Eggs or Very Young.

Agelena naevia
Mangora gibberosa
Micrathena gracilis
Ordgarius bisaccatus
Amaurobius americana
Araneus arenatus
Leucauge venusta
Micrathena sagittata

Hibernation Stage Undetermined.

Allocosa funerea
Acacesia foliata
Araneus angulatus
Araneus ectypa
Araneus marmoreus
Anyphaena pectorosa
Bathyphantes micraria
Castaneria longipalpus
Ceratinella brunnea
Icius hartii
Linyphia conferta
Linyphia marginata
Lycosa gulosa
Misumenops gulosa
Oxyptila monroensis
Philodromus minutus
Pedanostethus pumulus
Phrurolithus similis
Pirata febriculosa
Prosopotheca minuta
Synemosyna formica
Theridion differens
Theridion pennsylvanicus
Theridula opulenta
Tmarus angulatus
Xysticus fraternus

Specific Relation of the Species to the Association.

The study of almost any vegetation association discloses the presence of numerous individuals of species that are not characteristic or typical of the association. In general the greater the diversity of conditions within the association and the smaller the area the larger will be the proportion of such forms present. Although the area under study was of considerable size and collections were made well within the forest and for the most part in rather densely populated portions the occurrence of such species of spiders was fairly common. This made necessary a careful study of all species present to determine

the forms typical of the habitat and those that belonged elsewhere. The spiders present have been placed in the following four groups, Forest spiders, Transitional, Field and Miscellaneous.

Under Forest spiders is included those species that are regularly found in beech-maple as evidenced by numerous collections in this and other forests. This does not imply that these species are not found in other types of forest. Incomplete collections I have made in Oak-Hickory forest yield 46 of the same species while Weese (1924) gives about 40 of the same as being present in Elm-Maple forest. If as Blake (1926) suggests the mere presence of the forest cover rather than the character of the same is the major factor in distribution we may expect to find a large proportion of the same spiders in other types of dedicuous forests and to considerable extent even in the coniferous forest.

In the Transition group are those spiders that are found regularly and in largest numbers in the forest border or in regions where the timber has been cut off resulting in a mixed grassland-forest association.

Field spiders are those species found regularly in open grassland, pastures, and other areas denuded of trees and shrubs.

Forms undetermined, on account of scarcity, those ranging about equally over all the other groups and those more typical of different deciduous forests are placed under the heading Miscellaneous.

The distribution makes no pretense at being wholly accurate but is that indicated by the study of the selected region, miscellaneous collections in the same vicinity, those in other beech-maple forests and numerous collections of Dr. W. M. Barrows.

In the case of a considerable number of species the grouping is correct. In some instances, however, the number of individuals collected is not sufficient to make certain of the correct habitat. This is especially true of such forms as Hahnia radula, Lathys sp. (pallida?), Phrurolithus similis, Dictyna sublata, Linyphia conferta and the forms in the miscellaneous group marked insufficient data.

This arrangement does not signify that a species is limited to a given association but it does mean that it is found habitually and in greatest numbers in the habitat indicated.

The comparative abundance of different species found in a habitat is no criterion for the placing of a species. A species typical for one habitat may exceed numerically in another a species typical for that habitat. This may quite well be seen in the case of Agelena naevia. This spider is far more abundant in fields than in woods and is typically a field spider. It exceeds numerically, however, many of the typical forest spiders. The same condition has been found to prevail for animals in general in the Elm-Maple forest (Weese). Animal sub-dominants during a considerable period of the year are species which have migrated from or are in course of migration to the forest edge or adjacent meadow.

The grouping though inaccurate in some instances is presented in the hope that it may stimulate intensive collection on the part of those ecologically minded with resultant verification or necessary corrections.

FOREST SPIDERS (Beech-Maple).

Araneus marmoreus
Ariadne bicolor
Amaurobius bennetti
Cicurina arcuata
Cicurina brevis
Cicurina pallida
Coelotes hybridus
Coelotes longitarsus
Coelotes montanus
Coras medicinalis
Hahnia radula
Dolomedes fontanus
Lathys foxii
Lathys sp. (*pallida?*)
Bathyphantes zebra
Linyphia clathrata
Microneta cornupalpis
Ceraticelus minutus
Clubiona obesa
Clubiona pallens
Anyphaena pectorosa
Anyphaena saltabunda
Phrurolithus alarius
Phrurolithus palustris
Phrurolithis similis
Gongylidiellum pallidum
Oedothorax probatus
Prosopotheca minuta
Tmeticus aestivalis
Ceratinopsis interpres
Trachelocamptus rostratus
Uloborus americana
Hyptiotes cavatus
Araneus angulatus
Araneus arenatus
Araneus ectypus
Leucauge venusta
Micrathena gracilis
Steatoda borealis
Nodocion sp.
Sergiolus variegatus
Zelotes ater
Philodromus minutus
Xysticus fraternus
Castaneria cingulata
Castaneria longipalpis
Habrocestum pulex
Neon nellii

TRANSITIONAL SPIDERS.

Pisaurina mira
Pirata febriculosa
Dictyna foliacea
Dictyna minuta
Dictyna sublata
Ordgarius bisaccatus
Micrathena sagittata
Misumenops asperatus
Misumenops oblongus
Dendryphantes capitatus
Icius hartii
Xysticus nervosus
Theridion differens
Theridula opulenta
Linyphia conferta
Linyphia marginata
Linyphia phrygiana
Acacesia foliata
Synemosyna formica
Maevia vittata
Dendryphantes (Phid.) clarus

FIELD SPIDERS.

Agelena naevia
Tetragnatha laboriosa
Crustulina guttata
Theridion frondeum
Trachelas tranquillus
Mangora gibberosa
Allocosa funerea
Xysticus ferox
Araneus arabesca
Bathyphantes nigrinus

MISCELLANEOUS.

Amaurobius americana, forest, but more typically Oak-Hickory.
Hahnia agilis, field and forest; probably also transitional.
Herpyllus vasifer, woods under bark, chiefly Oak-Hickory.
Lycosa rabida, insufficient data.
Pedanostethus pumulus, insufficient data.
Bathyphantes micraria, insufficient data.
Ceratinella brunnea, insufficient data.
Oedothorax montiferus, insufficient data.
Diplocephalus exiguus, insufficient data.
Ero furcatus, insufficient data.
Theridion pennsylvanicus, insufficient data.
Lycosa gulosa, insufficient data.
Oxyptila monroensis, insufficient data.
Eustala anastera, insufficient data.
Tmarus angulatus, insufficient data.
Oedothorax platyrhinus, insufficient data.
Schizocosa crassipes, all habitats.
Dendryphantes (*Phid.*) *audax*, all habitats.

COMPARATIVE ABUNDANCE OF THE SPECIES.

Observations and collections were carried on in the selected environment over a period of approximately sixteen months. Numerous collections were made of a general nature during this period. It was quite apparent from general observation that certain species were much more abundant than others. With a view to determining the relative abundance of the species quantitative collecting was done in the selected region. These collections were made from April 13, 1928 to April 10, 1929 approximately every two weeks except during the winter months when conditions were constant for a longer period. All individuals of such collections were saved, siftings being gone over carefully within a few hours after collection. Every effort was made to equalize the time and attention given to different situations and species in order that the true conditions might best be represented. One of the most difficult and time consuming features in connection with this was the identification of the young spiders. These were carefully sorted and kept, sometimes for several weeks until an adult was found and identified after which successive growth stages were carefully compared and the species determined.

Some of all the species found were present in the Special Collections. The species present and the total number of each were as follows:

INDIVIDUALS AND SPECIES PRESENT IN THE SPECIAL COLLECTIONS.

Ariadne bicolor	56	*Ceratinopsis interpres*	69
Amaurobius americana	16	*Diplocephalus exiguus*	26
Amaurobius bennetti	158	*Trachelocamptus rostratus*	14
Agelena naevia	106	*Uloborus americana*	18
Cicurina arcuata	143	*Hyptiotes cavatus*	8
Cicurina brevis	7	*Acacesia foliata*	6
Cicurina pallida	22	*Araneus angulatus*	4
Coelotes hybridus	53	*Araneus arabesca*	27
Coelotes longitarsus	146	*Araneus arenatus*	42
Coelotes montanus	6	*Araneus ectypus*	4
Coras medicinalis	32	*Araneus marmoreus*	71
Hahnia agilis	154	*Eustala anastera*	4
Hahnia cinerea	23	*Mangora gibberosa*	134
Hahnia radula	9	*Ordgarius bisaccatus*	1
Pisaurina mira	82	*Leucauge venusta*	109
Dolomedes fontanus	53	*Tetragnatha laboriosa*	5
Allocosa funera	6	*Micrathena gracilis*	11
Lycosa gulosa	4	*Micrathena sagittata*	154
Lycosa rabida	7	*Ero furcatus*	8
Schizocosa crassipes	18	*Herpyllus vasifer*	3
Pirata febriculosa	2	*Nodocion sp.*	9
Oxyptilus monroensis	3	*Sergiolus variegatus*	2
Dictyna foliacea	84	*Zelotes ater*	8
Dictyna minuta	16	*Philodromus minutus*	3
Dictyna sublata	16	*Misumenops asperatus*	56
Lathys foxii	18	*Misumenops oblongus*	5
Lathys sp. (pallida?)	4	*Tmarus sp. (angulatus?)*	4
Pedanostethus pumulus	3	*Xysticus ferox*	10
Crustulina guttata	18	*Xysticus fraternis*	184
Steatoda borealis	6	*Xysticus nervosus*	7
Euryopis funebris	7	*Clubiona obesa*	39
Theridion differens	2	*Clubiona pallens*	19
Theridion frondeum	264	*Anyphaena pectorosa*	16
Theridion pennsylvanicum	6	*Anyphaena saltabunda*	101
Theridula opulenta	3	*Phrurolithus alarius*	110
Bathyphantes micraria	2	*Phrurolithus palustris*	260
Bathyphantes nigrinus	4	*Phrurolithus similis*	7
Bathyphantes zebra	21	*Trachelas tranquillus*	4
Linyphia clathrata	50	*Castaneria cingulata*	16
Linyphia conferta	2	*Castaneria longipalpus*	2
Linyphia marginata	5	*Synemosyna formica*	1
Linyphia phrygiana	16	*Maevia vittata*	27
Microneta cornupalpis	11	*Habrocestum pulex*	25
Ceraticelus minutus	4	*Dendryphantes (Phid.) audax*	10
Ceratinalla brunnea	5	*Dendryphantes capitatus*	167
Gongylidiellum pallidum	244	*Dendryphantes (Phid.) clarus*	15
Oedothorax montiferus	3	*Icius hartii*	6
Oedothorax platyrhinus	4	*Neon nellii*	31
Oedothorax probatus	196		
Prosopotheca minuta	8	*Total*	4201
Tmeticus aestivalis	209		

Examination of the list as to representation of the species in the total population makes apparent the fact that a com-

paratively small number of species make up the greater proportion of individuals present. The principal species and their numerical relation to the total number of spiders present are here given.

Species Represented by 100 or More Individuals.

Amaurobius bennetti
Agelena naevia
Cicurina arcuata
Coelotes longitarsus
Hahnia agilis
Theridion frondeum
Congylidiellum pallidum
Oedothorax probatus
Tmeticus aestivalis
Mangora gibberosa
Leucauge venusta
Micrathena sagittata
Xysticus fraternus
Anyphaena saltabunda
Phrurolithus alarius
Phrurolithus palustris
Dendryphantes capitatus

The above 17 species, or 17.1% of the total number of species, constitute 67.6% of the total number of individuals in the special collections.

Species Represented by 50 or More Individuals.

Ariadne bicolor
Coloetes hybridus
Pisaurina mira
Dolomedes fontanus
Dictyna foliacea
Linyphia clathrata
Ceratinopsis imterpres
Araneus marmoreus
Misumenops asperatus

The above total of 26 species, or 26.2% of the entire number of species, equals 81.2% of all individuals in the special collections.

Species Represented by 25 or More Individuals.

Coras medicinalis
Diplocephalus exiguus
Araneus arabesca
Araneus arenatus
Clubiona obesa
Maevia vittata
Habrocestum pulex
Neon nelli

The above 34 species, or slightly more than a third (34.2%) of all species, aggregate 3,664 individuals or 87.2% of the total 4,201 individuals in the eighteen special collections from April 13, 1929, to April 10, 1928, inclusive.

Summary and Conclusions.

Ninety-nine species of spiders were present in the forest studied, thirty-four of which constitute 87.2% of the total number of individuals.

Numerically dominant species of spiders present in the Beech-Maple forest are not always typical forest spiders but may be forest edge, transitional or even field forms which migrate into the forest.

There is in the Beech-Maple forest a stratification of spider population which correlates with that of the physical factors and the vegetation.

Of the spiders whose specificity for the association was determined 49 were typical beech-maple 21 transitional and 9 typical field forms.

Hibernation of spiders is preceded by a downward migration of the spider population apparently resulting from the changing physical factors, temperature probably being the most important of them. Physical factors in winter become dominant, biotic negligible.

The majority of the spiders winter over as immature or adult forms, this being true of 65 of the 73 species whose overwintering stage was determined.

A Seasonal succession of societies was shown by the spiders of the forest studied, these being represented by a few principal species two or three of which were easily numerical dominants.

The Spider population of Beech-Maple forest exhibits two high peaks, late spring and early fall. The high peak of autumn is not due to the presence of new species but to the appearance of young of the species which matured in late spring.

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THE ALGAL FOOD OF PIMEPHALES PROMELAS.
(Fathead Minnow)*†

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INTRODUCTION.

In recent years increasing interest has been shown by icthyologists and those people concerned with fish culture regarding the food of our common fishes. The interest at the present time is centered in the study of the food of the possible species which may be used as forage fish for bass or other carnivorous pond fishes. *Pimephales promelas*, Rafinesque, the fathead minnow, is a species under such consideration. The purpose of this paper is to describe the food of the fathead with special emphasis on the algal food, but also with mention of such animal forms and other materials found in the alimentary canal. This work has been carried on for over a year at the Botany Department of the Ohio State University and at the Franz Theodore Stone Laboratory at Put-in-Bay, Ohio.

The writer wishes to express her gratitude to those people who so kindly aided in the preparation of this paper: to Dr. L. H. Tiffany, of Ohio State University, for suggesting and directing the problem; to Mr. E. L. Wickliff, of the Ohio State Division of Fish and Game, for furnishing material for study; to Mr. Milton Trautman, for collecting some of the materials used; and to Dr. R. V. Bangham, of the College of Wooster, for helpful suggestions and for interest shown during the progress of the work.

METHODS OF COLLECTION AND STUDY.

The minnows were collected by means of a fine-meshed seine. They were placed immediately in a ten per cent formalin solution to preserve the contents of the stomach and intestine. Later a longitudinal slit was made in the ventral body wall and the alimentary canal was removed. Each alimentary

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canal was placed in a small shell vial filled with 6-3-1 preservative (6 parts water, 3 parts 95% alcohol, and 1 part formalin). When a detailed study was made of the contents of the alimentary canal small bits were removed and microscopic slides were prepared. Permanent glycerin mounts for future reference were made of the stomachic or intestinal contents of each fish observed. The slides were studied first under the medium and then the high powers of the compound microscope with the occasional use of the oil immersion. The content of many of the alimentary canals was spread out in flat dishes and was studied under the low power of the compound microscope.

Two hundred three fish were studied. The size ranged from 6 centimeters long, which is practically the maximum length of the fathead, to 2.7 centimeters. The measurements were taken from the point of the snout to the base of the caudal fin.

FEEDING HABITS.

Up to the present time there has been little work done on the feeding habits of *Pimephales promelas*. According to Forbes and Richardson (5): ". . . . . it belongs to the mud-eating group of minnows, and its alimentary structures correspond to this fact, the intestine being two to three times the length of the head and body, and the pharygeal teeth not hooked but with well developed grinding surface. Our only knowledge of its food is derived from a study of four specimens from muddy streams in northern and central Illinois. The intestines of these were largely filled with mud containing some algæ and a considerable number of insects, partly of terrestrial species and partly aquatic larvæ of Diptera."

Lord (13) in the discussion following his paper (p. 96) on *The Blackhead Minnow As a Forage Fish* given at the Meetings of the American Fisheries Society at Hartford, Connecticut, in August, 1927, says: ". . . . . the blackhead (= fathead) minnow, after it reaches a certain size, say forty millimeters, can be seen browsing along on the stems of aquatic plants, scraping off the diatom slime and small algæ. It is not a carnivorous fish so far as can be seen."

A study of the alimentary canals of *Pimephales promelas* certainly shows that it belongs to the mud-eating group of minnows. In practically every one of the fish studied which were taken from the streams or small rivers the alimentary

canals were filled, sometimes even gorged, with sand and silt. Mixed in with the silt were found the plant and animal remains. This would tend to indicate that the fathead also feeds near the bottom, taking in mud, plant and animal food, and organic remains. Specimens taken from regions along Lake Erie show a decided decrease in the amount of mud present, (in some cases it was entirely absent), but by far the greater number of fatheads is found in the muddy creeks or in small sluggish rivers; so it seems they can be considered as belonging to the mud-eating group. Judging from the predominance of fragments of Oscillatoria in the stomachic and intestinal contents, it would seem that the minnow nibbles, to a certain extent at least, on that filamentous blue-green. Broken filaments of Oedogonium and Spirogyra were observed frequently while it was not at all uncommon to find short or even quite long filaments of other filamentous greens. Whether these were nibbled directly from the plant mass or whether they entered the fish by accident as water was taken into the mouth during respiration cannot be said. The filamentous greens were found to be very much more abundant and the filaments themselves were much longer than were those observed by Tiffany (20) in his work on the algal food of the young gizzard shad.

ORGANISMS COMPRISING THE FOOD.

Only a few statements have been made by investigators concerning the food of the fathead. Reference has been made in the preceding paragraph to the report of Forbes and Richardson (5) on the food of *Pimephales promelas*.

Forbes (6) in another paper says: ". . . . about three-fourths of the intestine consisted of mud, the remainder being wholly insects. These were partly terrestrial species, occurring accidentally in the water, and partly aquatic larvæ of Diptera. The vegetable food of these specimens amounted to about one per cent, chiefly various unicellular Algæ."

Pearse (15) in giving a quantitative summary of the food of three specimens in per cent says, "Tanytarus gregarious larvæ, 79.3; mites, 1.6; amphipods, 0.3; Cyclops, 2.6; oligochaetes, 6; diatoms and other algæ, 1.3; and debris, 8.3."

Lord (13) found that "after a size of 25 to 30 mms. was reached the fish were observed feeding on algæ to a great extent. It is thus non-competitive with game-fish."

It seems that the habitat in which the fish are taken determines to a great extent what will be found in the alimentary canal. The fish which were investigated came, for the most part, from streams in southwestern Ohio. One lot of minnows was collected June 24, 1928, in White Oak Creek, Brown County, and also in the East Fork of the Miami River, Clermont County, when the waters were high and the streams were full of mud. These fish were found to be filled with mud or silt and plant and animal food proved to be rather scarce. The algal forms consisted almost entirely of Closteriums, Diatoms, and various species of Euglena along with filaments of Rhizoclonium and disintegrated Spirogyra. The Entomostraca were proportionately much more scarce than were the fragments of leaf tissue, tracheæ, and epidermal hairs which were found mixed in with the mud. In fact many of the fish showed practically no indication of having taken in animal food.

On the other hand a few fish were collected in Maumee Bay, at the mouth of the Maumee River, and also at the mouth of the Portage River which showed a varied diet of many small algal forms and Entomostraca. These fish were practically devoid of mud.

The remainder of the fish, taken from various streams of the Ohio River drainage system, showed a very large percentage of mud, but they also showed a larger percentage of algal species as well as a slightly larger percentage of animal forms.

Of the animal forms observed, the Entomostraca were by far the most abundant. The Cladocera were found most frequently with the Copepoda being second in importance. The Ostracoda were found to be much less abundant than were the other two orders. Other animal forms that were observed were Rotifers, Nematoda, and the remains of a few small insects. Setæ of the freshwater Oligochaeta and masses of pigment cells were frequently found. Very often the only evidence of animal food was an occasional appendage or perhaps a furcal ramus of a copepod.

Pimephales promelas is considered by some to be more of an animal than a plant feeder, but present observations do not indicate that such is the case. Further it does not appear to be nearly so much of an animal feeder as Kraatz (11) has shown *Pimephales notatus* to be.

The algal material found in the alimentary canal is probably the only plant material which is used for food to any great

extent. The blue-greens are very abundant as compared with the number found by Tiffany (20) in the gizzard shad. The different type of habitat of the fathead probably accounts for this increase. The number of species of the Protococales, (Chlorococcales) is much smaller, while the species lists of Desmids, Euglenoidia, and filamentous greens are much longer than those reported by Tiffany (20). Not only can differences in the habitats account for the variations in the algal forms found in the alimentary canals of the two fish, but also the types of gill rakers present in the fish can offer some explanation for these variations. The gill rakers of *Pimephales promelas* are much shorter and are much fewer in number than are those of the gizzard shad. This fact alone can probably account for the scarcity in the numbers of the Protococcales reported for the fathead.

ALGAL FOOD.

Table I shows the 128 species and varieties of algæ which were identified in the alimentary canals of the 203 fatheads investigated. The table is arranged to show the relative abundance of the species according to two general habitats: (a) bays and the mouths of several rivers in the western end of Lake Erie (indicated by "Erie"), and (b) streams and small rivers of the Ohio River drainage system (indicated by "O. R. D."). "R" in the table refers to rare or occasional, "C" to common, and "A" to abundant. When the letter x is found in two columns under the same general habitat, for a single species, it means that the abundance of the species is one or the other depending upon the locality in which the fish were collected.

TABLE I.

Algal Species or Variety	Erie			O. R. D.		
	R	C	A	R	C	A
Myxophyceæ.						
Aphanocapsa pulchra (Kuetz) Raben	x				x	
Chroococcus limneticus Lemm	x					
" " var. *distans* G. M. Smith	x					
" *turgidus* (Kuetz) Naeg				x		
" *varius* A. Braun				x		
Coelosphaerium kuetzingianum Naeg		x		x		
" *naegelianum* Unger	x			x		
Gloeocapsa dubia Wartmann	x					
" *gelatinosa* Kuetz	x					

TABLE I—Continued.

Algal Species or Variety	Erie			O. R. D.		
	R	C	A	R	C	A
Gomphosphaeria lacustris Chodat	x			x		
Merismopedia elegans A. Braun				x		
" *glauca* (Ehr) Naeg		x	x			x
" *punctata* Meyen		x		x		
" *tenuissima* Lemm		x		x		
Microcystis aeruginosa Kuetz	x			x		
" *flos-aqua* (Witt) Kirch		x		x		
" *incerta* Lemm	x	x				
" *pulvera* (Wood) Migula	x					
Lyngbya aestuarii (Mert) Lieb				x		
" *birgei* Smith				x		
" *? cryptovaginata* Schkorb				x		
" *kuetzingiana* Kirch				x		
" *? lutea* (Ag.) Gomont				x		
Oscillatoria amoena (Kuetz) Gomont				x		
" *brevis* Kuetz				x		
" *laetevirens* (Crouan) Gomont					x	
" *limosa* Agardh	x					x
" *princeps* Vauch				x	x	
" *sancta* Kuetz				x		
" *tenuis* Agardh		x				x
Phormidium ? molle (Kuetz) Gomont	x					
Anabaena lemmermanni P. Richter	x	x				
Anabaena spp?	x			x		
Nodularia paludosa Wolle				x		
Gleotrichia natans (Hedw.) Rab				x		
Chlorophyceæ.						
Eudorina elegans Ehr	x					
Sphaerocystis schroeteri Chodat				x		
Pediastrum boryanum (Turpin) Menegh		x		x		
" *clathratum* (Schroeter) Lemm. var. *microporum* Lemm				x		
" *duplex* Meyen	x					
Pediastrum duplex Meyan var. *clathratum* A. Braun	x					
" *simplex* (Meyen) Lemm						x
Dictyosphaerium ehrenbergianum Naeg	x					
" *puchellum* Wood	x					
Westella botryoides (W. West) de Wildeman	x					
Ankristrodesmus falcatus (Corda) Ralfs	x			x		
" *setigerus* forma *minor* (Schroder) G. S. West				x		
Schroederia judayi G. M. Smith	x					
Coelastrum microporum Naeg	x					
Kirchneriella obesa (W. West) Schmidle	x	x				
Oocystis borgei Snow	x	x				
" *elliptica* W. West forma *minor* W. West				x		
Actinastrum gracillimum G. M. Smith	x					
Scenedesmus abundans (Kirch) Chodat	x					
" *bijuga* (Turpin) Lager		x			x	
" *denticulatus* Lager	x					
" *dimorphus* (Turpin) Kuetz		x		x		
" *obliquus* (Turpin) Kuetz	x			x		
" *opoliensis* P. Richter	x				x	
" *quadricauda* (Turpin) de Bréb			x			x
" " var. *parvus* G. M. Smith	x			x		

TABLE I—Continued.

Algal Species or Variety	Erie			O. R. D.		
	R	C	A	R	C	A
Scenedesmus quadricauda var. *quadrispina* (Chodat) G. M. Smith	x			x		
Tetraedron minimum (A. Braun) Hansg	x					
" *tropicum* W. & G. S. West				x		
Stigeoclonium tenue (Ag.) Kuetz				x		
Geminella minor (Naeg) Heer				x	x	
Ulothrix tenerrima Kuetz	x					
Cladophora crispata (Roth) Kuetz				x		
" *glomerata* (L.) Kuetz				x	x	
Rhizoclonium hieroglyphicum (Ag.) Kuetz					x	
Bulbochaete spp?				x		
Oedogonium exospirale Tiffany				x		
Oedogonium spp?	x				x	
Spirogyra spp?						x
Closterium acerosum (Schrank) Ehr	x					x
" " (Schrank) Ehr. var. *elongatum* Bréb				x	x	
" " (Shrank) Ehr. var. *minus* Hantz				x		
" *lanceolatum* Kuetz	x				x	
" *lunula* (Mull) Nitz. var. *intermedium* Gutw				x		
" *moniliferum* (Bory) Ehr	x			x		
" *peracerosum* Gay var. *elegans* G. S. West				x		
" *leibleinii* Kuetz				x		
Closterium pronum Bréb				x		
" *ulna* Focke				x		
Cosmarium adoxum West & G. S. West				x		
" *angulossum* Bréb				x		
" *bireme* Nordst				x		
" *cytomatoplerum* Nordst				x		
" *didymochondrum* Nordst	x					
" *garrolense* Roy & Biss	x			x		
" *laeve* Rab		x		x		
" *logiense* Bis	x					
" *obtusatum* Schmidle				x		
" *pyramidatum* Bréb				x		
" *reniforme* (Ralfs) Arch				x		
" *speciosum* Lund. var. *simplex* Nordst	x			x	x	
" *undulatum* Corda var. minutum Tittr	x	x				
Hyalotheca dissiliens (Smith) Bréb				x		
Penium margaritaceum (Ehr) Bréb				x		
Pleurotaenium ehrenbergii (Bréb) De Bary				x		
Staurastrum paradoxum Meyen	x			x		
Heterokonteæ.						
Tribonema bombycinum Agardh	x					
Euglenineæ.						
Euglena acus Ehr					x	x
Euglena fusca (Klebs). Lemm				x		
" *pisciformis* Klebs				x		
" *spirogyra* Ehr	x					
" " Ehr. var. *laticlavius* (Huber) Lemm				x		
" " Ehr. var. *marchia* Lemm				x		
" *spiroides* Lemm	x				x	

TABLE I—Continued.

Algal Species or Variety	Erie			O. R. D.		
	R	C	A	R	C	A
Phacus longicauda (Ehr.) Duj	....	....	....	x	....	....
" *pleuronectes* (O. T. M.) Duj	....	....	....	x	....	....
" *triqueter* Ehr	....	....	....	x	....	....
PERIDINIEÆ.						
Peridinium aciculiferum Lemm	....	....	....	x	....	....
" *inconspicuum* Lemm	....	....	....	x	....	....
DIATOMEÆ (BACILLARIEÆ).						
Melosira distans (Ehr) Kuetz	....	x	....	....	....	....
" *varians* Agardh	x	....	....	x	....	....
Coscinodiscus lacustris Grunow	....	x	....	....	....	....
Tabellaria fenestra (Lyng) Kuetz	....	x	....	x	....	....
Meridion circulare Agardh	....	....	....	x	....	....
Synedra spp?	....	x	....	....	x	....
Cocconeis placentula Ehr	....	x	....	....	x	....
Cocconeis spp?	....	....	....	....	....	x
Rhoicosphenia curvata (Kuetz) Grunow	....	....	....	x	....	....
Navicula spp?	....	....	x	....	....	x
Pinnularia divergens W. Smith	....	....	....	x	....	....
Pinnularia spp?	....	x	....	....	x	....
Gyrosigma kuetzingii Grunow	x	....	....	....	....	x
" *scalproides* Rab	x	....	....	....	x	....
" *spenceri* W. Smith	....	....	....	x	....	....
Gomphonema acuminatum Ehr	....	....	....	x	....	....
Amphora ovalis Kuetz	....	....	....	....	x	....
Epithemia argus Ehr	....	....	....	x	....	....
Nitzschia sigmoides (Nitz) W. Smith	....	....	....	x	....	....
" *vermicularis* (Kuetz) Hantz	....	....	....	x	x	....
Cymatopleura solea Bréb	x	....	....	....	....	x
Surirella biseriata (Ehr) Bréb	....	....	....	x	....	....

SUMMARY OF THE DISTRIBUTION OF SPECIES AMONG THE ALGAL GROUPS.

Table II is a summary of all the algal forms found, giving numbers of the genera, families, orders, and divisions.

TABLE II.

MYXOPHYCEÆ, 34.

CHROOCOCCALES	18
Chroococcaceæ	18
Aphanocapsa	1
Chroococcus	4
Coelosphaerium	2
Gloeocapsa	2
Gomphosphaeria	1
Merismopedia	4
Microcystis	4
HORMOGONEALES	16
Oscillatoriaceæ	13
Lyngyba	5
Oscillatoria	7
Phormidium	1
Nostocaceæ	2
Anabaena	1
Nodularia	1
Rivulariaceæ	1
Rivularia	1

CHLOROPHYCEÆ, 63.

Isokontæ, 35.

VOLVOCALES	2
Volvocaceæ	1
Eudorina	1
Palmellaceæ	1
Sphaerocystis	1
PROTOCOCCALES	27
Hydrodictyaceæ	5
Pediastrum	5
Dictyosphaeriaceæ	3
Dictyosphaerium	2
Westella	1
Autosporaceæ	19
Ankistrodesmus	2
Schroederia	1
Coelastrum	1
Kirchneriella	1
Oocystis	2
Actinastrum	1
Scenedesmus	9
Tetraedron	2
CHAETOPHORALES	1
Chaetophoraceæ	1
Stigeoclonium	1
ULOTRICHALES	2
Ulotrichaceæ	2
Geminella	1
Ulothrix	1
SIPHONOCLADIALES	3
Cladophoraceæ	3
Cladophora	2
Rhizoclonium	1

Stephanokontæ, 1.

OEDOGONIALES	1
Oedogoniaceæ	1
Bulbochaete	
Oedogonium	1

Akontæ, 27.

ZYGNEMALES	
Zygnemaceæ	
Spirogyra	
Desmidiaceæ	27
Closterium	10
Cosmarium	13
Hyalatheca	1
Penium	1
Pleurotaenium	1
Staurastrum	1

HETEROKONTEÆ, 1.

HETEROTRICHALES	1
Tribonemaceæ	1
Tribonema	1

EUGLENINEÆ, 10.

Euglenaceæ	10
Euglena	7
Phacus	3

PERIDINIEÆ, 2.

Peridiniaceæ	2
Peridinium	2

DIATOMEÆ (BACILLARIEÆ), 18.

CENTRICÆ	3
Melosiraceæ	2
Melosira	2
Coscinodiscaceæ	1
Coscinodiscus	1
PENNATÆ	15
Tabellariaceæ	1
Tabellaria	1
Meridionaceæ	1
Meridion	1
Fragilariaceæ	
Synedra	
Achnanthaceæ	2
Cocconeis	1
Rhoicosphenia	1
Naviculaceæ	4
Navicula	
Pinnularia	1
Gyrosigma	3
Gomphonemaceæ	1
Gomphonema	1
Cymbellaceæ	2
Amphora	1
Epithemia	1
Nitzschioideæ	2
Nitzschia	2
Surirellaceæ	2
Cymatopleura	1
Surirella	1

TOTAL NUMBER OF FORMS RECORDED	128

NOTES ON SOME ALGAL FORMS.

Pediastrum simplex (Meyen) Lemm.

This species was found to be by far the most abundant of all the species of Pediastrum. It can be recognized easily by the single process of the marginal cells of the coenobium and by the compact plate. The species as observed was found to be quite variable both as to the size of the coenobium and as to the length of the marginal process.

Cosmarium cymatopleurum Nordst.

Several specimens were observed each having the following dimensions: length 58μ; breadth 46μ; isthmus 15μ. West (24) gives for the dimensions of the species length 82–97μ; breadth 60–70μ; isthmus 25–30μ. The specimens observed fit the descriptions and diagram in West (24) except for the much smaller dimensions.

Cosmarium undulatum Corda var. **minutum** Wittr.

The specimens observed had the following dimensions; length 27μ; breadth 27μ; isthmus 6μ; while West (24) records the dimensions as being length 21–28μ; breadth 18–21μ; isthmus 8.5–10μ.

Cosmarium logiense Bissett.

The dimensions of the few specimens found were length 42μ; breadth 30.8μ; isthmus 11.5μ, while West's (24) dimensions are length 61–65μ; breadth 48–50μ; isthmus 16–18μ. The granules in the wall were too small and were entirely too numerous to consider the specimens as a variety of *Cosmarium reniforme* (Ralfs) Arch. They seemed to be closest to *Cosmarium logiense.*

Closterium pronum Bréb.

A single specimen was found and this seemed to be nearer to *Closterium pronum* than any of the related species, although it was somewhat larger. The species observed was 500μ in length, 11μ in breadth, with the apices measuring 3.65μ. *Closterium pronum* is recorded in West (24) as having a length of 313–423μ and a breadth of 5.7–9μ. This together with the variations noted under *Cosmarium pronum* is perhaps a distinct variety, but since only a single plant was observed, the complete diagnosis awaits further data.

Euglena spiroides Lemm.

Of the fairly large number of specimens observed several were noted which may be a larger variety of the species. *Euglena spiroides* (14) (23) is recorded as being 60–170μ long and 16μ in diameter, while these few specimens were from 219–269μ in length and were 23.4μ in diameter.

Oedogonium exospirale Tiffany.

This species was identified by a single isolated oospore. The oospore of *Oedogonium exospirale* can be recognized easily by the spiral ribs of the outer wall which unite at the poles of the spore.

Although filaments of Oedogonium were found many times, none of them contained fruiting cells so they could not be identified. Filaments showing the basal holdfast were noticed occasionally.

Bulbochaete spp.?

Bulbochaete occurred several times in the fish collected from southwestern Ohio, but the alga was never found in the fruiting condition.

Spirogyra spp?

Disintegrated Spirogyra was found many times, but the filaments were never seen conjugating. The lengths of the filaments varied considerably, some being but several cells in length, while others were very long.

Oscillatoria spp.?

The species list for Oscillatoria is shorter than it should be because fragmentation made absolute identification of the end cell extremely difficult. *Oscillatoria tenuis* was by far the most abundant of any of the algal species recorded.

Lyngbya ? cryptovaginata Schkorb.
Lyngbya ? lutea (Ag.) Gomont.

These species fit the descriptions in Pascher (8) except for the habitats.

The Lyngbyas as a whole were difficult to identify because of the fragmentation and isolation of the filaments. The species list is perhaps much longer than shown in Table I.

Phormidium ? molle (Kuetz) Gomont.

The species could not be identified absolutely from the single filament observed.

Diatoms.

The diatoms were extremely abundant, but only a few were identified. The genus Navicula, as would be expected, was the most common genus represented.

SUMMARY.

1. *Pimephales promelas* may well be considered as belonging to the mud-eating group of minnows. It is a bottom-feeder, taking in plant and animal food and organic remains along with large quantities of mud.

2. Although previous records tend to indicate that the fathead takes in more animal than plant food, present observations show that animal food is proportionately less abundant than is the plant food.

3. Two hundred three fish were examined and a total number of one hundred twenty-eight species and varieties of algæ were identified.

4. The 128 species and varieties are distributed among the classes of algæ as follows: Myxophyceæ 34, Chlorophyceæ 63, Heterokonteæ 1, Euglenineæ 10, Peridineæ 2, Diatomeæ 18.

5. The algal species found in the alimentary canal of the fathead depend upon the habitat in which the fish is taken; yet the number and size of the gill rakers of the fish determine to a great extent what forms are retained in the alimentary canal.

6. Since *Pimephales promelas* takes in but a small amount of animal food, it is not much in competition with the carnivorous fish. If the fatheads can be obtained in large enough numbers, therefore, they should be found desirable as a forage fish.

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THE MAJOR AND MINOR SULCI OF THE BRAIN OF THE SHEEP.

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Introduction.

A description of the constant and variable sulci of the cerebral hemispheres of the sheep brain is presented as a preliminary to the description of the cytoarchitecture. Owing to the lack of definite knowledge of the limits of cytoarchitectural zones the nomenclature of Krueg ('78) is followed. The same lack of knowledge makes it unsafe in many cases to name gyri and these have been omitted since a sulcus may lie on the border of a cell zone or within the zone. Krueg's excellent description covers a large series of ungulates indicating major, minor, and transient sulci as well as the order of appearance in embryonic stages along with a comparison with carnivores.

Krueg's paper does not include a large series of any one type and a description of a larger series of the sheep brain is needed in order to refer the description of the cytoarchitecture of a particular brain to the type or variations of the type. Fifty brains have been examined giving one hundred cases since the ordinary variations are as frequent on two hemispheres of the same brain as on the hemispheres of two different brains. For details of the insular area the papers and bibliographies of Clark ('96) and Holl ('00) should be consulted. The nomenclature of fissures, however, follows that of Krueg rather than that of Holl.

The Dorsal Surface.

(Fig 1)

The dorsal surface, aside from the f. longitudinalis, presents one tranverse fissure, the Sylvian, one transverse sulcus, ansatus (cruciatus), and five longitudinal sulci, coronalis, lateralis, entolateralis, ectolateralis and suprasylvius and one diagonal sulcus, the diagonal. The ansate and coronal sulci are described in detail under the rostral surface.

Of the four longitudinal sulci on the caudal surface of the hemisphere, two, the lateral (Fig. 1, L) and the suprasylvian (Figs. 1, S. S. A, S. S. M., S. S. P.), are constant as to their depth but somewhat variable as to their position. The s. entolateralis (Fig. 1, Enl.) (medialis Burkholder '04) and s. ectolateralis (Fig. 1, Ecl.) (lateralis Burkholder '04) are shallow and vary both in length and position. A good deal of variation exists in the names of sulci associated with s. lateralis. The name of s. lateralis follows the description of Krueg ('78) and the suggestion of Kappers ('21, p. 1152) that the s. lateralis is the deepest sulcus on the caudal portion of the dorsal surface.

The s. entolateralis (Fig. 1, Enl.) is shallow and quite variable in length but never entirely absent although it may be represented by detached depressions. When best developed it lies next to the f. longitudinalis parallel to s. lateralis. Its rostral end may join the s. lateralis or turn medially and end on the medial border of the hemisphere. Its caudal end usually extends to and sometimes completely around the caudal border of the hemisphere where it may bifurcate over the dorsal end of ramus horizontalis posterior. When not present as a continuous sulcus, the slight depressions occupying its position are too variable to describe.

The s. lateralis (Fig. 1, L.) (intermedius, Burkholder '04) is not more pronounced on superficial examination than entolateral and ectolateral but if it is examined in transverse sections or if it is opened it is found to be a deep sulcus with convoluted walls throughout the caudal two-thirds of its length while the lateral wall of the sulcus forms a well defined operculum over the medial wall. It penetrates the brain wall in a ventrolateral direction.

The s. lateralis is fairly constant in its position with reference to the f. longitudinalis, i. e., in its distance from the median border of the hemisphere and in the fact that its caudal end extends except in rare cases (one in one hundred) around the caudal border of the hemisphere where it may join or be continued as the r. occipitotemporalis (Fig. 3, Oct.). In the case mentioned the caudal end of lateralis is separated from the caudal end of ectolateralis by a gyrus and ectolateralis extends beyond the caudal border of the hemisphere. Any reduction in the length or depth of s. lateralis is likely to be compensated by changes in ectolateralis. The rostral end of lateralis is more variable and shallower than the caudal two-thirds. It usually

extends to the middle of the hemisphere, shifting to a more medial position and may end on the dorsal surface or extend around the medial border of the hemisphere and appear on the medial surface (Fig. 5, L.).

The s. ectolateralis (Fig. 1, Ecl.) (lateralis, Burkholder) is shallow and quite variable as to length and tends to appear as a series of detached depressions. In its simplest form as a continuous sulcus it occupies a position midway between lateralis and suprasylvius with its rostral end bounded by the gyrus just caudal to s. ansatus. In some brains its rostral end bifurcates, the medial branch ending at or near the medial border of the hemisphere or even appearing on the medial surface. It does not join suprasylvius or lateralis in its rostral portion.

The caudal third of s. ectolateralis, even its simplest form, varies greatly. It may reach the caudal pole of the hemisphere rarely, but is likely to be limited by a gyrus dorsal or medial to a ramus of s. suprasylvius (Fig. 4, S. S., 6) or be replaced by a series of shallow depressions quite variable in position. The simple form of the sulcus just described is in 50% of brains examined, replaced by a series of shallow depressions of which only the rostral portions have any degree of constancy. In no cases examined have two parallel depressions appeared representing s. ectolateralis. Even detached depressions indicate roughly the position of the simple form.

The s. suprasylvius (Figs. 1 and 4, S. S. A., S. S. M., S. S. P.) is a constant deep sulcus with convoluted walls and lies near the lateral border of the hemisphere forming an arch in its rostral third over the dorsal ramus of the f. of Sylvius and a gentler curve throughout its caudal two-thirds. It penetrates the brain wall in a ventromedial direction. In the rostral third of its extent it usually, just dorsal to the f. of Sylvius, gives off a shallow dorsal ramus (Figs. 1, S. S. 2) approaching or even joining s. ansatus and delimiting a triangular gyrus rostral to which it curves laterally (ventrally) around the lateral portion of s. ansatus beyond which it again curves medially usually ending in a bifurcation just caudal to s. diagonalis. Two rather frequent variations occur in this region. One due to the buried condition of the gyrus at the lateral border of s. ansatus which gives the appearance of a union of s. suprasylvius with the lateral border of s. ansatus and the other the continuation through a shallow groove of the rostral end of s. suprasylvius

(Figs. 1, S. S. 1) parallel with s. diagonalis. A connection between these two sulci is present in at least 50% of the brains examined but when present it is so shallow as not to alter the validity of Krueg's ('78) description of a constant s. diagonalis in the ungulates and invalidates Brodman's description (Kappers, p. 1187) of the s. diagonalis as an extension of the anterior ramus of s. suprasylvius in ungulates.

The s. suprasylvius presents a constant ventral ramus (Figs. 1 and 4, S. S. 5) varying in depth and sometimes connected by a shallow depression with the s. posticus. This ventral branch of s. suprasylvius varies in length and apparently in depth depending on the extent and depth of a dorsal ramus of s. posticus which lies when present just caudal to it. There is constantly present between this ramus and the f. of Sylvius a shallow depression (Fig. 1). The caudal end of the s. suprasylvius rarely reaches the caudal pole of the hemisphere. It usually ends in a bifurcation on the dorsolateral surface, the dorsal ramus of which may join the caudal end of the s. ectolateralis, the ventral branch usually joining the caudal end of the s. posticus. Any change in the bifurcation of the caudal end of the s. suprasylvius or the absence of fusions with s. ectolateralis and s. posticus are likely to be replaced by slight depressions of variable shape and depth.

The Rostral Surface.

(Fig. 2).

The constant sulci appearing on the rostral surface are the transverse sulci, ansatus (cruciatus) and splenialis, the horizontal sulci, coronalis, presylvius, diagonalis and the olfactory sulcus visible on depressing or detaching the olfactory bulb and tract.

The sulcus ansatus (Fig. 1 and 2 An.) is a deep sulcus with convoluted walls extending from the fissura longitudinalis, where it is visible on the median surface of the hemisphere, laterally nearly to sulcus suprasylvius from which it is separated by a curved gyrus which is sometimes buried giving the ansate sulcus the appearance of joining the sulcus suprasylvius. The s. ansatus penetrates the brain wall in a ventrocaudal direction so that the caudal wall forms an operculum over the rostral wall.

The sulcus splenialis (cruciatus? Krueg) described under the medial surface (Figs. 1 and 2 spl.) is quite constant and deep

varying only slightly in the degree to which it extends laterally from the longitudinal fissure.

The sulcus coronalis (Figs. 1 and 2 Co.) is the deepest sulcus on the rostral surface. Both medial and lateral walls are convoluted and the sulcus penetrates the brain wall in a ventrolateral direction, the lateral wall forming an operculum over the median wall. It begins caudally at the sulcus ansatus from which it extends rostrally sometimes bifurcating into lateral and medial rami but in most brains having only the lateral ramus, the medial ramus when absent is usually represented by a slight notch at the point of bifurcation. When the median arm is absent its position is sometimes indicated by a slight indentation (Figs. 1 and 2 Co. 1). The lateral ramus is always present and usually lies parallel with the rostral end of the presylvian sulcus. The walls of these rami both medial when present and lateral are convoluted.

The presylvian sulcus (Figs. 1 and 2 Prs.) is constant with convoluted walls and is nearly as deep as coronalis. It penetrates the brain wall in a dorsomedial direction. It ends between the rostral rami of coronalis when both are present or medial to the lateral ramus when the medial ramus is absent. The dorsal end of presylvius may sometimes join the lateral ramus of coronalis.

The olfactory sulcus (Fig. 2 Olf.) is visible on the rostral area when the olfactory bulb and tract are depressed or removed. It is a shallow sulcus in which the olfactory tract lies and is quite constant.

The sulcus rostralis (paraolfactorius, Burkholder) sometimes appears on the medial border of the hemisphere as a notch in f. longitudinalis about midway between ansatus and the rostral end of the brain.

The sulcus diagonalis (Figs. 1 and 2, D. A., D. 1.) lying on the lateral portion of the rostral area is always present but is quite variable in form. It is deep and its walls are usually convoluted. It penetrates the brain wall in a slightly ventromedial direction. Its simplest and most constant form is a nearly straight line beginning near the pars dorsalis of the Sylvian fissure and extending forward dorsally and medially nearly to the s. coronalis. It is usually separated from Sylvius and always from coronalis by well defined gyri. It is rarely continuous with suprasylvius as in some ungulates (Brodmann and Kappers ('21)). Continuity of these two sulci is some-

times indicated by a slight depression formed by a blood vessel. A more complicated form of diagonalis is represented by the presence of a ventral ramus (Figs. 1 and 2, D. 1.). This ventral ramus when present is almost as deep as the diagonal portion. When absent the ventral ramus is replaced by a detached sulcus. Sometimes the ventral ramus is continuous with a dorsal ramus (Figs. 4, S. A. 1.) of pars anterior of Sylvius or may even be replaced by it.

The Lateral Surface.

On the lateral surface of the brain all the constant depressions except the vertically placed f. of Sylvius have a general horizontal direction and even the f. of Sylvius has pronounced caudal and rostral rami lying horizontally.

The s. rhinalis (Figs. 3 and 4, R.) is quite constant in position and begins rostrally at the attachment of the olfactory tract to the ventral surface of the brain, extending caudally as a shallow groove to the level of the dorsal ramus of the f. of Sylvius where it becomes deep with convoluted walls and appears on the caudal surface of the hemisphere (Fig. 3, R.) extending sometimes almost to the dorsal border of the caudal surface.

The fissure of Sylvius (Figs. 4, S. D., S. A., S. P. 1) presents three constant portions. The terminology of Krueg ('78) and Kappers ('21) is adopted rather than that of Holl ('00). The pars dorsalis (Fig. 4, S. D.) (processus acuminis Krueg) extends almost to the dorsal border of the hemisphere. Its lateral walls are always deeply convoluted and sometimes show short depressions in the lateral walls running parallel with the floor of the main fissure. The caudal wall overlaps the rostral wall to some extent forming a slight operculum. The dorsal extremity of pars dorsalis occasionally bifurcates. Two additional anterior rami are sometimes found extending from the dorsal ramus of the f. of Sylvius. The more dorsal (Fig. 4, S. D. 1) may join the ventral ramus of the bifurcated s. suprasylvius and the more ventral ramus (Fig. 4, S. D. 2) may join the caudal end of the s. diagonalis.

The pars anterior is not only deep except at its anterior end but is much convoluted on both dorsal and ventral walls. This ramus penetrates the brain wall in a ventro-medial direction so that the buried portion of the dorsal wall is concealed by the ventral wall. The rostral end of this ramus usually

bifurcates and the ventral ramus (Fig. 4, S. A. 2) may be continuous by a shallow depression with the s. presylvius, while the dorsal ramus (Fig. 4, S. A. 1) sometimes joins the ventral ramus of s. diagonalis or replaces it. It is sometimes connected also with the presylvian sulcus by a shallow depression (Fig. 4, S. A. 3) at the level of the bifurcation.

The pars posterior of the f. of Sylvius is short, but deep with convoluted walls and presents two rami a caudal and a ventral both of which are constant, the ventral ramus (Fig. 4, S. P. 2) (transinsular fissure of Clark '96) joining rhinalis. This ventral ramus is the only deep sulcus reaching s. rhinalis. Other transverse depressions rostral to it are either quite shallow or simply depressions caused by blood vessels.

Holl ('00) who has made a study of the insula of the ungulate brain includes the ventral wall of the posterior ramus of the fissure of Sylvius and the gyrus lying ventral to the anterior ramus of the fissure of sylvius (gyrus orbitalis Burkholder) in the insula (gyrus arcuatus 1 Holl). The gyrus surrounding pars dorsalis is labeled (arcuatus II Holl). This gyrus is bounded dorsally by s. suprasylvius. It extends rostrally to the middle of the s. diagonalis and caudally to the caudal ramus of the s. suprasylvius and includes the gyri surrounding the s. posticus.

The presylvian sulcus (Fig. 4, Prs.) is constant and deep with convoluted walls, the dorsal wall forming an operculum over the ventral wall. The sulcus penetrates the brain in a ventro-medial direction. It begins usually just ventral to the rostral end of the anterior ramus of the f. of Sylvius. It may be connected as mentioned above by a shallow depression with the ventral branch of the bifurcated f. of Sylvius but is usually quite detached from it. It may appear sometimes to be connected also with f. of Sylvius more caudally at the level of the bifurcation but this connection (Fig. 4, S. A. 3) is quite inconsistent and shallow and is caused by a blood vessel. This sulcus (Figs. 1 and 2, Prs.) extends around the rostral pole of the hemisphere and ends on the rostral surface between the bifurcated branches of s. coronalis or when the medial ramus is absent, which frequently happens, at the extreme rostral tip of the hemisphere lying parallel with the lateral ramus of s. coronalis.

The suprasylvian or arcuate sulcus is the most extensive sulcus on the lateral surface. It is quite deep with convoluted

walls. This sulcus penetrates the brain in a slightly ventromedial direction especially in the pars media so that the ventral wall overlies the dorsal wall to some extent. It extends from just rostral to the pars dorsalis of the f. of Sylvius, in the form of an arch, almost to the caudal pole of the hemisphere. It is usually divided into a pars anterior (Figs. 1 and 4, S. S. A.) a pars media (Figs. 1 and 4, S. S. M.), a pars posterior (Figs. 1 and 4, S. S. P.) portions. The terminations of the anterior and posterior portions which are shallower than the pars media, being more variable in arrangement.

The pars media is the most constant and usually presents one shallow dorsal ramus, (Figs. 3 and 4, S. S. 2) directly dorsal to the end of the f. of Sylvius. As mentioned in describing the dorsal surface, the rostral portion of pars media (Fig. 4, S. S. C.) seems sometimes to be continuous with the lateral end of the s. ansatus owing to the depressing of the gyrus at the lateral termination of that sulcus.

The variations of pars anterior depend upon the form of the s. diagonalis. The pars anterior usually bifurcates into an anterior ramus (Fig. 4, S. S. 3) and a ventral ramus (Fig. 4, S. S. 4). Both rami are deep at the point of bifurcation and gradually become shallower toward their terminations. The anterior ramus rarely joins s. diagonalis and when this occurs it is by a shallow depression. In four cases, however, out of one hundred examined the depression was pronounced. The short ventral ramus (Fig. 4, S. S. 4) of the bifurcated rostral end may occasionally join and sometimes be replaced by a ramus from the f. of Sylvius (Fig. 4, S. D. 1) in the same relative position.

The caudal border of the pars media of s. suprasylvius is indicated by a constant and fairly deep ventral ramus (Fig. 4, S. S. 5). It is never entirely absent but varies in length and depth depending on the depth and form of s. posticus. From this ventral ramus the pars posterior forms a gentle curve maintaining its depth and convoluted wall almost to the caudal border of the hemisphere. The caudal portion of this sulcus is quite variable but usually bifurcates into a dorsal ramus (Fig. 4, S. S. 6) which frequently reaches the caudal border and is connected sometimes with the caudal end of s. ectolateralis (Fig. 4, Ecl.) or with detached depressions in the usual position of the caudal end of that sulcus. The ventral ramus (Fig. 4, S. S. 7) is still more variable but rarely absent and may be

connected with the caudal ramus of s. posticus and when absent be replaced by a branch from s. posticus.

The s. diagonalis (Fig. 4, D. A., D. P.) is a constant deep sulcus and penetrates the brain in a ventromedial direction. In 75% of the brains examined it is a simple diagonal depression beginning caudally near the middle of pars dorsalis of the f. of Sylvius and extending diagonally, rostrally and medially nearly to the middle of s. coronalis with which it never forms a junction. The caudal end of the sulcus is occasionally continuous with the f. of Sylvius by a transient anterior ramus of that fissure (Fig. 4, S. D. 2). This simple form of the diagonal sulcus is always accompanied by slight depressions both ventral and dorsal to the main sulcus. Owing to the presence of a ventral ramus in 25% of the cases examined the anterior and posterior halves are indicated as ramus anterior (Fig. 4, D. A.) and ramus posterior (Fig. 4, D. P.) respectively. In 25% of the brains examined there is a ventral ramus (Figs. 1, 2 and 4, D. 1) arising near the middle of the s. diagonalis and extending ventral and cephalad sometimes joining the anterior ramus (Fig. 4, S. A. 1) of the Sylvian fissure. This ramus is not as deep as the anterior and posterior rami and when absent is replaced by the slight depression mentioned above. The slight dorsal depression (Fig. 4, D. 2) mentioned above is sometimes continuous with the anterior ramus of diagonalis.

The s. posticus is a deep sulcus present in all brains examined and usually presents an anterior, a posterior and a somewhat inconstant and shallower dorsal ramus and a similar ventral ramus. In a few cases the anterior and posterior portions are detached from each other and the detached portions with the dorsal and ventral rami form a stellate figure. The anterior and posterior rami are the deepest and most constant portions. The anterior ramus (Fig. 4, P. A.) extends rostrally nearly to the f. of Sylvius which, however, it never joins. It usually ends just ventral to the ventral ramus (Fig. 4, S. S. 5) at the caudal border of pars media of s. suprasylvius. The caudal ramus extends nearly to the caudal border of the hemisphere and frequently bifurcates, its dorsal ramus sometimes joining s. suprasylvius (Fig. 4, S. S. 7). When the caudal ramus is short its caudal portion is replaced by a detached shallow depression. The dorsal and ventral rami (P. D., P. V.) are more variable than the anterior and posterior rami. The dorsal ramus is rarely absent, is short and deep and is

situated more cephalad than the ventral ramus. The ventral ramus (Fig. 4, P. P.) is sometimes absent and is replaced by a detached depression occupying the same relative position.

The Medial and Caudal Surfaces.
(Figs. 3 and 5).

The caudal and concealed portions of the medial surfaces of the hemisphere are exposed by a transverse incision and removal of the brain stem at the level of the mammillary body.

On the buried medial surface of the hemisphere two depressions, the hippocampal fissure and fimbriodentate sulcus appear constantly. Both are shallow even the hippocampal fissure cannot be readily opened.

The fimbriodentate sulcus (Fig. 5, Fd.) lies rostral to the hippocampal fissure between the fimbria and the gyrus dentatus and extends throughout the whole arch of the buried portion of the hemisphere appearing on the flat medial surface in front of the more anterior of two prominent elevations of gray matter ventral to and slightly rostral to the splenium of the corpus callosum.

The hippocampal fissure (Fig. 5, H.) lies caudal to the fimbrio-dentate sulcus between the gyrus dentatus and the gyrus hippocampi and extends throughout the whole arch of the buried medial surface of the hemisphere. It appears on the flat medial surface of the hemisphere when a median longitudinal section of the brain is made and is visible between the two small gray elevations mentioned above. These two gray elevations are usually labeled in the text books as fasciola cinerea. The anterior of these two gray masses is the dorsal limit of the gyrus dentatus and the posterior elevation is a continuation of the gyrus hippocampi.

On the flat medial surface of the hemisphere four sulci are always present with slight variations to be mentioned later with the addition of transient sulci belonging to the dorsal surface of the hemisphere.

The sulcus corporis callosi (Fig. 4, C.) is constant but shallow and extends throughout the length of the dorsal border of the corpus callosum and well around both genu and splenium.

The rostral area of the medial surface presents two constant moderately deep sulci: the s. genualis (Fig. 5, G.) of Krueg and Kappers (s. cinguli Burkholder) and the more rostral s.

rostralis (Fig. 5, Ro.) of Krueg and Kappers (parolfactorius Burkholder).

The sulcus genualis (Fig. 5, G.) begins cephalad ventral to the genu of the corpus callosum and arching around the corpus callosum extends to the middle of that structure. It is sometimes quite simple in structure but often presents a well defined dorsal ramus (Fig. 5, G. 1) just rostral to the anterior end of s. splenialis and sometimes a ventral ramus (Fig. 5, G. 2). This dorsal ramus may be absent or represented by a slight depression and may occasionally be situated more rostral and invade the area usually occupied by s. rostralis.

The s. rostralis (Fig. 5, Ro.) is more variable than genualis. In its most regular form it parallels the course of s. genualis lying nearer the rostral border of the hemisphere forming an arch beginning ventral to the rostral end of s. genualis and arching around extends caudally to the gyrus just rostral to the s. splenialis where it may reach the edge of the hemisphere. Its variations consist in its appearing as two detached depressions in some cases and occasionally in the detached portions being separated by a ramus of s. genualis.

A constant sulcus (Fig. 5, Pc.) appears caudal to the splenium of the corpus callosum occupying the same relation to the splenium that s. genualis occupies with reference to the genu. It is a short sulcus and varies both in depth and length and when least pronounced is represented by a slight depression. It is not named in any description of the sheep brain. It is indicated in many ungulate brains by Krueg ('78) and occupies the position of the subparietoccipital fissure of the anthropoids. Since the sulcus is always present it is named from its position sulcus post callosus, since the term retrosplenialis is preempted. Its position indicates that it is in an olfactory area (regio retrosplenialis of Campbell).

The sulcus splenialis (Fig. 5, Spl.) is the most extensive and deepest sulcus on the medial surface of the hemisphere and is much convoluted in its caudal half. It has a well defined diagonal direction ventrolaterally as it penetrates the hemisphere so that its ventral wall forms an operculum over its dorsal wall. It begins rostrally on the dorsal surface of the hemisphere (Figs. 1 and 3, Spl.) just in front of the s. ansatus and extends in an arch below the dorsal border of the hemisphere to the caudal border where it bifurcates into a dorsal and ventral ramus, the ventral ramus (Figs. 3 and 5, R. S.) being the sulcus

retrosplenialis of Kappers and the dorsal ramus (Figs. 3 and 5, H. P.), which is frequently shorter and shallower, being the ramus horizontalis posterior of Kappers. These two rami are never absent in the brains examined but vary somewhat in length and depth. A rather common variation in the rostral portion of s. splenialis is the presence of a dorsal ramus (Fig. 5, Spl. 1) frequently reaching the dorsal border of the hemisphere and lying just caudal to the s. ansatus (Fig. 5, An.) and between that sulcus and the s. lateralis when it reaches the medial border of the hemisphere.

On the caudal surface of the hemisphere the s. rhinalis (Figs. 3 and 5, R.) is always present. Sometimes it ends well toward the lateral surface of the caudal area and may be continuous with the caudal end of s. suprasylvius. In other cases it lies more medial and is in one brain continuous with the caudal end of s. lateralis of the dorsal surface. These variations seem to be correlated with the form and extent of a third sulcus which Kappers ('21 p. 1126) calls the occipito-temporal sulcus. This is sometimes a detached sulcus in the sheep but is frequently represented by the caudal extension of s. lateralis. The modeling of the caudal surface is usually determined by the length and depth of the ramus horizontalis posterior, s. lateralis and s. rhinalis. When the simpler arrangements are not present, that is, well pronounced caudal extensions of splenialis, lateralis and rhinalis detached depressions occur. The s. occipitotemporalis is best defined when lateralis is short and does not appear on the caudal surface of the hemisphere. This indicates a close relation between occipito-temporalis when present and s. lateralis. When occipito-temporalis is best defined it lies parallel and between retro-splenialis (Fig. 3, Rs.) and rhinalis (Fig. 3, R.).

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EXPLANATION OF PLATES.

In all figures primary or deep sulci and fissures are indicated by heavy lines, shallow sulci are indicated by fine lines, transient sulci are indicated by broken lines. A shallow sulcus is likely to be transient, but when it is of value as a landmark in localization it is sometimes indicated by a fine line and its transient character is noted in text.

Plate I.

Fig. 1. Dorsal surface × 1.75.

Fig. 2. Rostral surface × 1.5.

Fig. 3. Caudal surface × 1.5. Fig. 3, in order to show the relation of sulci on the caudal surface to sulci on other surfaces includes more than the area in contact with the cerebellum which is taken as the caudal surface. The sulci shown in Fig. 3 are visible after the removal of the cerebellum.

Plate II.

Fig. 4. Lateral surface × 1.75.

Fig. 5. Medial surface × 1.75. The brain stem was removed by a transverse incision at the level of the mammillary body.

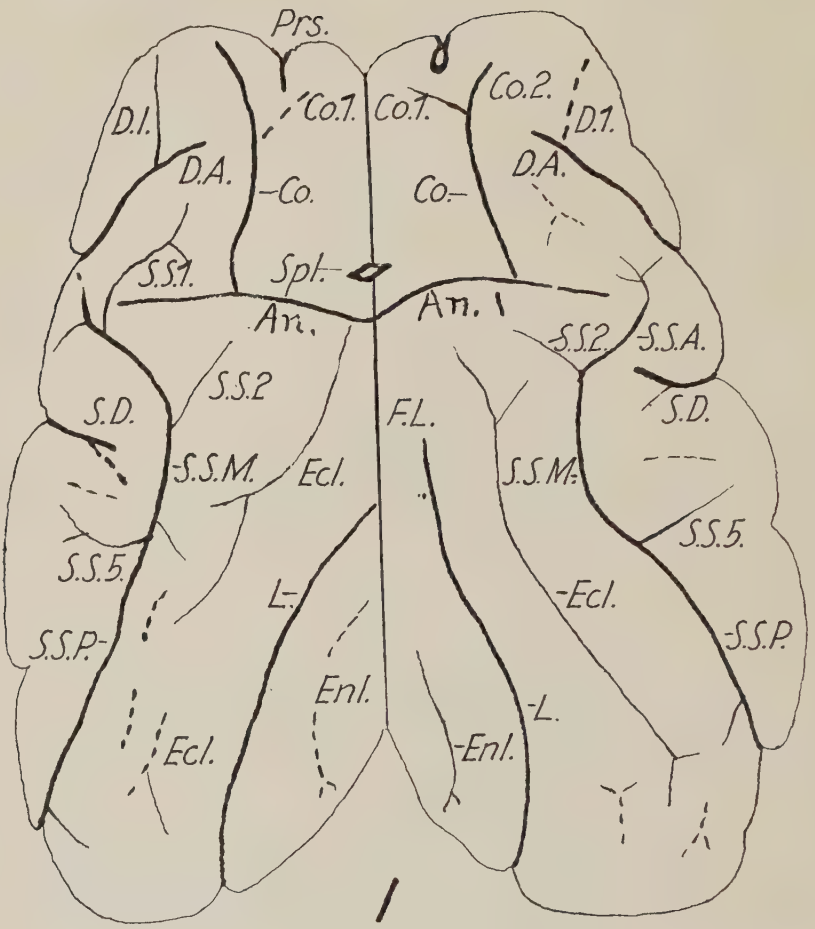
Note.—The determination of the relative depth of sulci on formalin fixed material is easily accomplished by immersing brains in tap water for some time, when the hemisphere wall becomes flexible and gyri are easily opened.

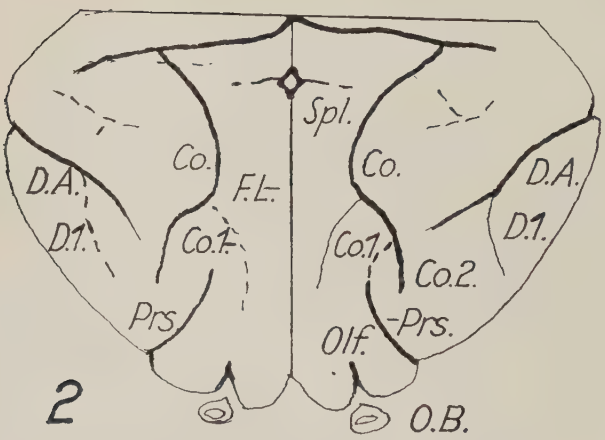
ABBREVIATIONS.

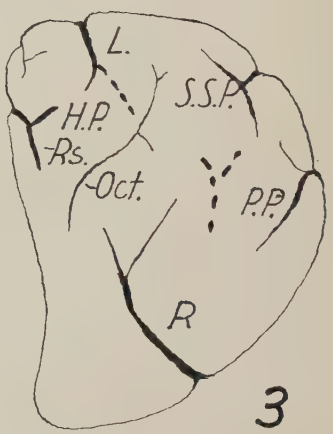
An.	sulcus ansatus (cruciatus?).
C.	sulcus corporis callosi.
C. A.	commissura anterior.
C. C.	corpus callosum.
C. O.	sulcus coronalis.
C. O. 1.	sulcus coronalis, ramus medialis.
C. O. 2.	sulcus coronalis, ramus lateralis.
D. A.	sulcus diagonalis, ramus anterior.
D. P.	sulcus diagonalis, ramus posterior.
D. 1.	sulcus diagonalis, ramus ventralis.
D. 2.	sulcus diagonalis, ramus dorsalis.
Ecl.	sulcus ectolateralis.
Enl.	sulcus entolateralis.
Fd.	sulcus fimbriodentatus.
F. L.	fissura longitudinalis.
For.	fornix.
G.	sulcus genualis (cinguli).
G. 1.	sulcus genualis, ramus dorsalis.
G. 2.	sulcus ganualis, ramus ventralis.
H.	fissura hippocampi.
H. P.	sulcus splenialis, ramus horizontalis posterior.
L.	sulcus lateralis.
M.	massa intermedia.
O. B.	bulbus olfactorius.
Oct.	sulcus occipitotemporalis.
Olf.	sulcus olfactorius.
P. A.	sulcus posticus, ramus anterior.
Pc.	sulcus postcallosus.
P. P.	sulcus posticus, ramus posterior.
P. D.	sulcus posticus, ramus dorsalis.
P. V.	sulcus posticus, ramus ventralis.
Prs.	sulcus presylvius.
R.	sulcus rhinalis.
Ro.	sulcus rostralis (paraolfactorius).
Rs.	sulcus retrosplenialis.
S.	septum pellucidum
S. A.	fissura Sylvii, pars anterior.
S. A. 1.	fissura Sylvii, pars anterior, ramus dorsalis.
S. A. 2.	fissura Sylvii, pars anterior, ramus medialis.
S. A. 3.	fissura Sylvii, pars anterior, ramus ventralis.
S. D.	fissura Sylvii, pars dorsalis.
S. D. 1.	fissura Sylvii, pars dorsalis, ramus dorsalis.
S. D. 2.	fissura Sylvii, pars dorsalis, ramus ventralis.
S. P. 1.	fissura Sylvii, pars posterior.
S. P. 2.	fissura Sylvii, pars posterior, ramus ventralis.
Spl.	sulcus splenialis.
Spl. 1.	sulcus splenialis, ramus dorsalis.
S. S. A.	sulcus suprasylvius, pars anterior.
S. S. 1.	sulcus suprasylvius, pars anterior, ramus anterior.
S. S. 3.	sulcus suprasylvius, pars anterior, ramus medialis.
S. S. 4.	sulcus suprasylvius, pars anterior, ramus ventralis.
S. S. M.	sulcus suprasylvius, pars media.
S. S. 5.	sulcus suprasylvius, pars media, ramus ventralis.
S. S. 2.	sulcus suprasylvius, pars media, ramus dorsalis.
S. S. P.	sulcus suprasylvius, pars posterior.
S. S. 6.	sulcus suprasylvius, pars posterior, ramus dorsalis.
S. S. 7.	sulcus suprasylvius, pars posterior, ramus ventralis.

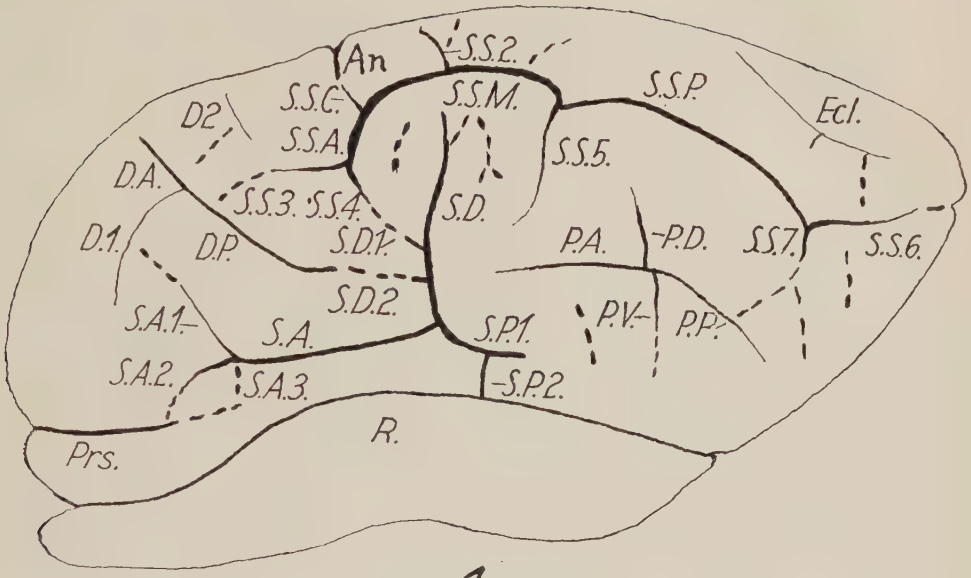
Sulci of the Brain of Sheep
F. L. Landacre

PLATE I.





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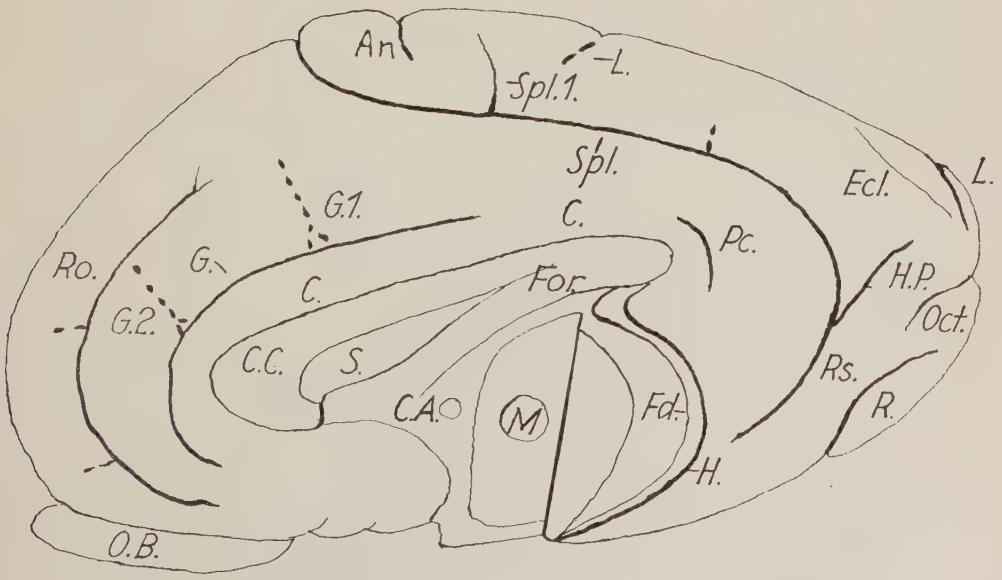
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5

ADDITIONAL SPECIES FROM THE SILICA SHALE OF LUCAS COUNTY, OHIO.

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Introduction.

Since the publication of my earlier study on the Fauna of the Silica Shale of Lucas County, in 1927* additional collecting from this shale over a period of two years has yielded eight more species. These are represented by very few specimens, but it seems worth while to record them inasmuch as three of them are apparently new. The species described in this paper are: *Favosites nitella; Stropheodonta demissa var.; Terebratula mediocris* n. sp.; *Leiorhynchus kelloggi; Tornoceras uniangularis; Isochilina scapha* n. sp.; *Leperditia* (?) *subrotunda* (?); *Bythocypris indianensis.*

An excavation on the floor of the quarry of the Sandusky Cement Company within the past year has revealed an additional two and a half feet of the Silica shale. This shale is not continuous with that above but is separated from it by an eight-inch limestone layer which forms the quarry floor at the north end. No systematic collecting has been done from this lower shale horizon but so far as observed there is no marked variation in the faunal content from that in the shale above.

Description of Species.

PHYLUM *COELENTERATA*

CLASS *ANTHOZOA*

Subclass *TABULATA*

Genus **Favosites** Lamarck

Favosites nitella Winchell

(Plate I, Fig. 1.)

1866. *Favosites nitella* Winchell, Rept. Low. Pen. of Mich., p. 89.
1876. *Favosites nitella* Rominger, Geol. Surv. Mich., Vol. III, Foss. Corals, p. 33. Pl. XI, Fig. 4.
1899. *Favosites nitella* Lambe, Contrib. to Can. Palaeon., Vol. IV, Pt. 1, p. 17.

*Stewart, Grace A. Geol. Surv. Ohio, Bull. 32, 1927.

Rominger's Description, 1876.—"Tubes rounded-polygonal, subequal, stout-walled, not fully one millimeter in width. Tube channels smooth or beset with distant lateral squamæ. Diaphragms partially simple, regular, partially of complicated irregular form through intersection with the lateral squamæ. Pores large, distant, in a single row on each side. Mode of growth globular or pyriform or digitato-ramose."

Remarks.—One discoidal colony attached to an Atrypa shell conforms very well with the characters of this species. The specimen is about 2 inches in diameter. The corallites are prismatic, small, scarcely a millimeter in diameter. Here and there are interspersed larger, circular tubes slightly more than a millimeter across. The pores and squamæ are imperfectly shown. The species has been found quite abundantly at higher horizons in the Devonian formations of Northwest Ohio.

PHYLUM *MOLLUSCOIDEA*

CLASS *BRACHIOPODA*

ORDER *PROTREMATA*

Genus **Stropheodonta** Hall

Stropheodonta demissa var.

(Plate I, Fig. 2.)

A few specimens of *Stropheodonta demissa* (Conrad) are at hand which are not entirely typical of the species, in that they do not have the striations stronger and more elevated on the umbo of the valves and becoming distinctly smaller and more numerous from there to the margin. Instead the striations bifurcate very close to the beak, and then are uniformly strong and of the same size until very close to the margin. Here they bifurcate and become much finer, and additional fine striæ are intercalated between them. A few striations bifurcate midway between the umbo and anterior margin.

Because of these differences the specimens are considered to represent a variety of the typical species.

Figured specimen, No. 16532, Geological Museum, Ohio State University.

ORDER *TELOTREMATA*

Genus **Leiorhynchus** Hall

Leiorhynchus kelloggi Hall

(Plate I, Figs. 3, 4).

1867. *Leiorhynchus kelloggi* Hall, Pal. New York, Vol. IV, p. 361, Pl. 57, Figs. 1–12.
1893. *Leiorhynchus kelloggi* Hall and Clarke, Pal. New York, Vol. VIII, Pt. II, p. 194, Pl. 59, Figs. 18–20, 32, 33.

Description.—Shell of moderate size; biconvex; transversely ovate to suborbicular; slightly wider than long, although in some cases the length and width are equal. Cardinal margins meeting beak at obtuse angle; lateral margins rounding uniformly to the anterior margin which is sinuate. The dimensions of an average sized specimen are: Length 25 mm., width 26 mm. A more orbicular specimen has a length and width of 24 mm.

Pedicle valve moderately to strongly convex on the umbo, flattening out on the lateral slopes, and anteriorly becoming depressed into a wide flaring sinus. Beak small, erect, rising only slightly above the brachial beak, perforated by a small foramen. Brachial valve more convex than the pedicle, curving regularly to the lateral margins; about the middle of the shell developing a low, broadly expanding fold. Beak curving under that of the pedicle valve. A median septum, with elongate muscle scars on either side, is present on the interior of the brachial valve.

Each valve marked by low, rounded, radiating plications which are usually less distinct in the umbonal region; commonly five or six are in the sinus, and an equal number on the fold, but occasionally as many as ten have been noticed. Six or seven poorly developed plications are present on the lateral slopes. Fine concentric striations are present on well-preserved specimens, and in some cases less distinct radiating ones are also present.

Remarks.—This species was originally described by Hall from specimens which came from the Olentangy shale in the northern part of Ohio, where they have been found in profusion in some places. Only two or three specimens have been found in the shale pit of the Sandusky Cement Company at Silica, but an abundance of them have been found at other horizons of the Devonian in northwest Ohio. Along Tenmile creek just south of Silica, some shaly limestone blocks dredged up from the bottom of the creek have yielded numerous excellent specimens. Stratigraphically this limestone is about twenty-five feet above the Silica shale of the Sandusky Cement Company quarry. The specimens are identical with those described by Hall from the Olentangy shale on the east side of the anticline.

The shape, small erect beak, and the weak development of the plications on the umbonal region are outstanding characters of the species.

Genus **Terebratula** Klein.

Terebratula mediocris n. sp.

(Plate I, Figs. 5–7.)

Description.—Shell of moderate size; rostrate, biconvex, elongate ovoid in outline; becoming flattened anteriorly, with evenly rounded anterior margin. The dimensions of the type specimen are: Length, 20 mm., width, 16 mm., with the greatest width anterior to the middle of the shell.

Pedicle valve moderately and uniformly convex from the beak to a little beyond the middle and then flattening quite noticeably to the anterior margin. Beak arcuate, rising some distance above the beak of the opposite valve; moderately incurved; perforated by a round foramen. Deltidial plates closing the greater part of the delthyrium. Cardinal slopes rounded.

Brachial valve shorter than the pedicle valve, moderately convex, the greatest convexity in the middle of the valve; depressed slightly anteriorly. Beak low, incurved below the beak of the opposite valve.

Surface of both valves marked by fine concentric growth lines, which near the anterior margin become crowded into rather prominent wrinkles. Shell structure finely punctate. Internal characters not observed.

Remarks.—Only one specimen of this species has been collected. It appears to be a well-marked species since it does not entirely conform to any described species of the genus known to the writer. The specimen most closely approaches *Terebratula sullivanti* Hall, from which it differs in its greater convexity, and in having an evenly rounded anterior margin instead of an emarginate one. From *Terebratula roemingeri* Hall it differs in the larger size. It resembles *Terebratula harmonia* Hall but that species is flatter and the beak is more erect.

Holotype, No. 16534, Geological Museum, Ohio State University.

PHYLUM *MOLLUSCA*

CLASS *CEPHALOPODA*

ORDER *AMMONOIDEA*

Genus **Tornoceras** Hyatt

Tornoceras uniangularis (Conrad)

(Plate I, Figs. 8, 9.)

1842. *Goniatites uniangularis* Conrad, Jour. Acad. Nat. Sci. Phila., Vol. 8, p. 268, Pl. 16, Fig. 4.
1879. *Goniatites uniangularis* Hall, N. Y. Palaeon., Vol. V, Pt. 2 (1), p. 444, Pl. 71, Fig. 14; Pl. 72, Figs. 6, 7; Pl. 74, Fig. 2.

Description.—Shell small, discoidal, having a diameter of about 12 mm. Only about two volutions are present on the specimen examined, but according to Hall a complete mature specimen probably has about four. Whorl section broadly oval, the dimensions on a septum near the living chamber being: Width 5 mm.; height 4 mm. Lateral surfaces almost flat.

Volutions compressed, gradually enlarging in size, in close contact, each one being deeply impressed on the preceding one. Umbilicus a small shallow depression. Living chamber not preserved, so that character of aperture is not known.

Well defined sutures on the cast of the interior mark the edges of the septa, and show the outline of the numerous cameræ. The sutures are a series of lobes and saddles, closely arranged at the umbilical margin, diverging and curving towards the aperture to form prominent saddles, then recurving to form deep lateral lobes; on the ventrilateral margins the saddles are shallower and narrower than on the lateral surface; the ventral lobe is narrow and conspicuously pointed.

Siphuncle not well shown on the specimen examined, but specimens of this species from elsewhere show it to be small and situated just beneath the test on the ventral side, and expanding anteriorly between the adjacent septa.

Shell characteristics not observed.

Remarks.—Only one small incomplete specimen of this neat little cephalopod has been obtained from the Silica shale, but it preserves very well the outstanding characteristics of the species. The species has not been recorded previously from the Devonian rocks of Ohio, but has been reported from the Hamilton and Portage shales of New York, and from rocks of Hamilton age in western Canada. The compressed state of the whorls and the prominent curving and recurving of the sutures to form saddles and lobes are the characters used in identifying this species.

PHYLUM *ARTHROPODA*

CLASS *CRUSTACEA*

SUBCLASS *OSTRACODA*

Genus **Leperditia** Rouault

Leperditia (?) subrotunda (?) Ulrich

(Plate I, Fig. 10.)

1890. *Leperditia (?) subrotunda* Ulrich, Cinc. Soc. Nat. Hist., Vol. 13, p. 181, Pl. 16, Figs. 1a, b, c.

One incomplete right valve with a portion of the anterior end missing is insufficient for accurate specific determination, and is doubtfully referred to this species. The specimen is small having a length of about 1.50 millimeters, and a height of 1 millimeter, the greatest height occurring almost in the middle of the shell. Valve moderately convex and more or less depressed toward the margin all the way round. Dorsal edge straight, curving with somewhat rounded angles to the anterior and posterior margins; ventral margin slightly triangular. Anterior margin more projecting and less broadly rounded than the posterior. Sub-centrally the shell is marked by a rounded muscle imprint; otherwise the surface is smooth and shows no indication of an eye tubercle.

This little shell is most closely connected with *Leperditia* (?) *subrotunda* Ulrich in its appearance, but is relatively wider, and the ends are more narrowly rounded.

Genus **Isochilina** Jones

Isochilina scapha n. sp.

(Plate I, Figs. 11, 12.)

Description.—Carapace very small, transversely elongate, canoe-shaped in form. Viewed dorsally the shell is elliptical in outline, the posterior end swollen in appearance as contrasted with the thinner anterior end. The dimensions of a perfect specimen are: Length 1.25 mm.; height .75 mm.; thickness, .50 mm. Valves moderately and evenly convex, the right one flattened a little marginally except along the dorsal edge. Dorsal margin straight or very slightly convex, merging into moderately rounded cardinal angles of which the anterior is the sharper of the two. Ventral margin straight, curving gradually into the rounded ends, the posterior end being more broadly rounded than the anterior. An oval sulcus occurs along the hinge. Surface smooth and even, with no sign of either muscle spot or eye tubercle.

Remarks.—This species is represented in our collections by one perfect specimen. It approaches *Isochilina fabacea* Jones

in its characters, but it does not have the finely reticulate surface of that species, and the ends are more uniformly rounded.

Holotype, No. 16538, Geological Museum, Ohio State University.

Genus **Bythocypris** Brady

Bythocypris indianensis Ulrich

(Plate I, Fig. 13.)

1890. *Bythocypris indianensis* Ulrich, Journ. Cinc. Soc. Nat. Hist., Vol. 13, p. 197, Pl. 16, Figs. 11a, b, c.

Description.—A small slender carapace having a length of about 1 millimeter and a height of .75 millimeters. Biconvex, subovoid, transversely oblong, the ends unequal. Left valve the larger and overlapping the right, the greatest overlap on the dorsal margin. Dorsal margin arched, postero-cardinal angle more pronounced than the other. Ventral margin slightly convex, curving to the ends of which the posterior is the more blunt. Eye tubercle distinct, a little anterior to the center in position. Surface smooth.

Remarks.—A few minute specimens have been collected from the Silica shale which in their general characteristics agree very well with this species. Stauffer questionably reported the species from the Devonian beds in northwest Ohio.

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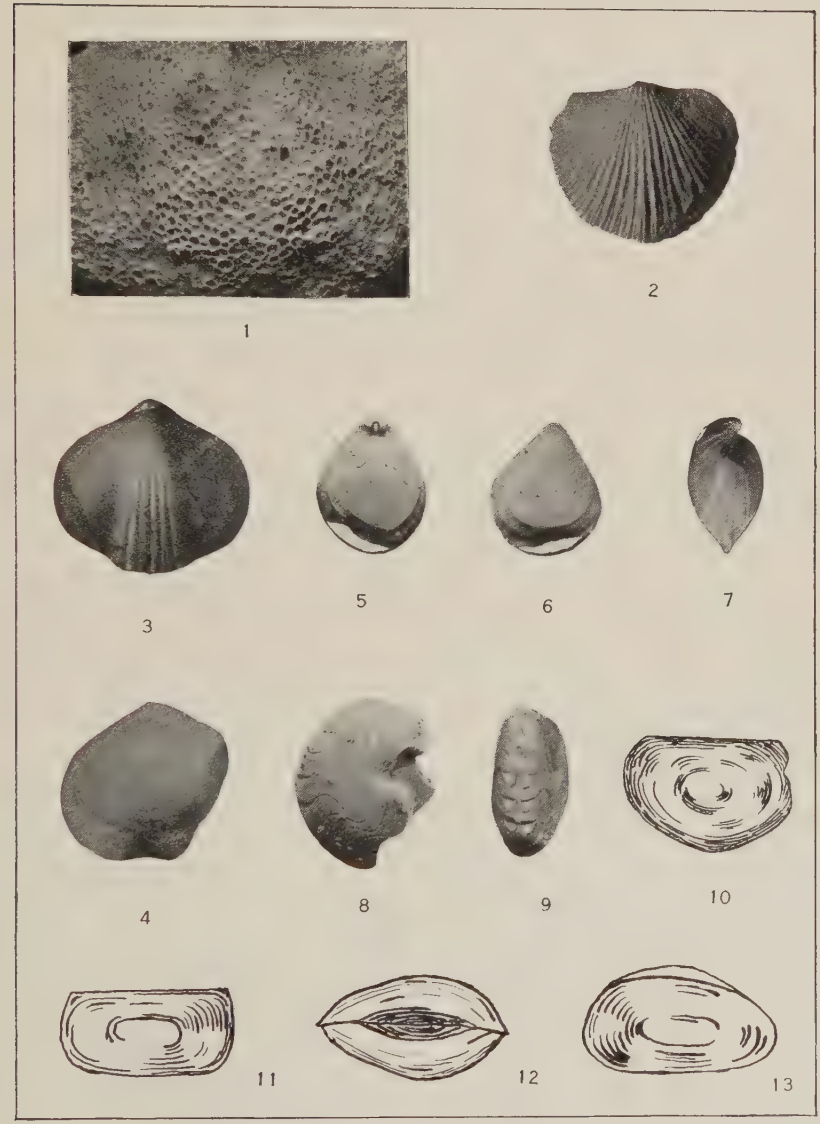
Fig. 12. Dorsal view. ×20.

Fig. 13. *Bythocypris indianensis* Ulrich. View of right valve showing left valve overlapping only on the dorsal margin. ×20..... 58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ORTHOGENETIC SERIES RESULTING FROM A SIMPLE PROGRESSIVE MOVEMENT*.

Studies in Determinate Evolution III.

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The five cases of orthogenetic series presented below will illustrate the general principle evident in endless numbers of characters from one end of the plant kingdom to the other. The progression in perfection of the main characteristic of each series apparently depends on the progressive evolution of a single mutative property, except in the last example given, which appears to involve several additional harmonious movements before the extreme is reached. As intimated in a previous paper, although the series in each case probably represents some of the actual evolutionary steps which the highest members took in attaining to their advanced condition of perfection, we are at present not so much concerned with the details of the actual movement as we are in presenting the phenomena of the series for consideration. For it is self-evident that no theories of heredity and no theories of evolution are worthy of serious consideration by the scientist, who is attempting to fathom some of the mysteries of nature, unless they take these things into account. At present, almost any presentation, even though based on the most profoundly irrational philosophy and taking no account of the volume of biological knowledge so far amassed and tested as to its reality, when masquerading under the name of science and assumed authority, is able to take possession of the very citadel of scientific education. The plant taxonomies, for example, which are persistently perpetuated offer a most profound contradiction to any rational theory of evolution. Yet it is practically impossible to get a manual of plants which shows any influence whatever of the modern phylogenetic studies. To continue to use a system of taxonomy which makes evolution untenable and at the same time teach the subject as a scientific

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dogma is like persisting in the belief that the world is the flat fixed center of the universe and at the same time teaching the unfortunate student that the earth revolves around the sun. A correct taxonomy is the first requirement of a correct understanding of evolution just as much as a correct evolutionary viewpoint is a necessary basis for a correct taxonomy. The two are interdependent. The same may be said in relation to evolution and genetics. A genetics which does not go parallel with phylogenetic taxonomy is no genetics at all.

1. A PROGRESSIVE SERIES IN THE REDUCTION OF THE CARPELLATE BRACT OF ABIES.

(See Figure 1).

The reduction of the leaf blade of the sporophyll is evident in many independent groups of vascular plants, and not only is this reduction manifest in the individual series but there is a consistent progression in the reduction in the entire series of vascular plants from the lowest ferns to the highest composites. The example given shows this progression in the fir. The same characteristic progression can be traced in other groups of conifers having ovuliferous scales. In Abies the movement is very prominent.

In the bristle-cone fir (*Abies venusta* (Dougl.) Koch. (Fig. 1-a) the carpellate bract is about three times as long as the ovuliferous scale and is still very leaf-like in texture. *Abies nobilis* Lindl. (Fig. 1-b) shows a considerable change, the carpellate bract being less than twice as long as the ovuliferous scale, and in *Abies fraseri* (Pursh) Poir. (Fig. 1-c) the reduction is still greater. In *Abies cephalonica* (Endl.) Loud. (Fig. 1-d) the carpellate bract is shorter than the ovuliferous scale and decidely membranous. The final steps, represented by *Abies grandis* Lindl. (Fig. 1-e), and *A, lasiocarpa* (Hook.) Nutt. (Fig. 1-f), bring the carpellate bract down to a mere vestigial appendage at the base of the ovuliferous scale. All the species of fir will come into this series in this respect, ranging from the bristle-cone fir to the alpine fir. In the firs the prominent ovuliferous scale remains fairly uniform, but the reduction of the carpellate bract has no relation to the uniformity of the ovuliferous scale. The carpellate blade or bract shows an orthogenetic reduction also in groups in which the ovuliferous scale is evolving to a great size as well as in groups in which no ovuliferous scale whatever is developed.

The progressive reduction of the carpellate bract might be considered morphologically as an evolution backward or as a loss of something that was formerly possessed, but this would be an entirely superficial and erroneous point of view. The evolution is through the acquirement of a progressive potentiality of the protoplast. The carpellate bract is a leaf. In the lowest vascular plants with a simple hereditary system, the homologous lateral appendages, differentiated as foliage leaves and sporangium-bearing leaves, are essentially alike. The

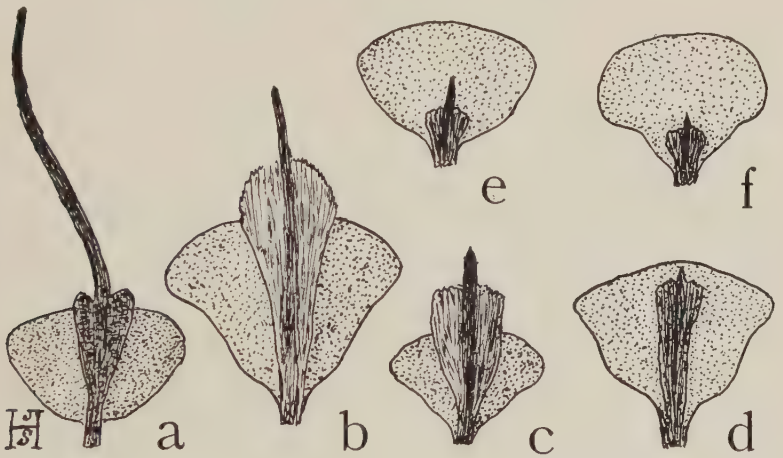

FIG. 1. Carpels of species of fir showing reduction in the size of the carpellate bract. a, *Abies venusta* (Dougl.) Koch., Bristlecone Fir. b, *A. nobilis* Lindl., Noble Fir. c, *A. fraseri* (Pursh) Poir., Fraser Fir. d, *A. cephalonica* (Endl.) Loud., Cephalonian Fir. e, *A. grandis* Lindl., Grand Fir. f, *A. lasiocarpa* (Hook.) Nutt., Alpine Fir. All Figures natural size.

evolution progresses step by step in producing a more complex reaction system until the degree of difference is very great, as in the alpine fir. The difference is not due to a loss of anything but to the evolution of a more complex reaction system which can, from homologous leaf incepts, bring out not only an ordinary foliage leaf but also a highly specialized woody-membranous bract. In the lower firs the resemblance to a leaf is still considerable, in the more advanced species the resemblance is slight, while in very highly evolved plants the resemblance becomes unrecognizable.

Now this loss of leaf character of the megasporophyll is of no advantage or disadvantage to the plant, neither is there any advantage or disadvantage in the different lengths of this

vestigial organ to the different species of Abies. If the plant had few leaves the early loss of chlorophyll in any part might be a disadvantage but firs have an abundance of leaves so the extra food is not needed. Any utilitarian or selective explanation offered as a causative agent to account for this orthogenetic series would have to be dismissed as the childish guess of credulity.

2. THE PROGRESSIVE ENLARGEMENT AND PERFECTION OF THE AWN AND SPIKELET OF STIPA.

(See Plate I).

Just as the preceding case was a progression in the reduction of the sporophyll, so the present series represents an increase in the development of the lemma or outer flowering glume. Stipa is a highly evolved genus of grasses and we are, therefore, prepared for the development of a highly bizarre type of fruit, not because this type of fruit with its indurated flowering glumes, its sharp-pointed callus, and its remarkable awn, twisted and plumed, are peculiar to this group, they are evolved in many independent lines, but because when the protoplast becomes full of certain highly evolved potentialities the progression very commonly ends in very remarkable forms, which from one point of view may be regarded as abnormalities or freaks. Many of the remarkable characteristics of man himself belong to this category. Of course, this language is not to be interpreted as meaning that these forms have not come through the orderly progression of evolution but only that in them a large number of orthogenetic movements have culminated. Apparently the protoplast with a complex hereditary potentiality is more subject to large and extreme mutations than the protoplast which is comparatively unevolved and thus has comparatively few hereditary potentialities or complexities.

The fruits illustrated represent the entire mature spikelet as it falls out of the empty glumes. Figure 1 represents the fruit of *Stipa macounii* Scribn. This is a rather small structure whose parts could be duplicated in many other groups of grasses. It has only a short awn and the lower awl-point is not conspicuous. Nevertheless it has nearly all of the characteristics of the highly evolved species except the plumose hairs on the awn. *Stipa scribneri* Vas. (Fig. 2) and *Stipa viridula* Trin. (Fig. 3.) show considerable improvement in the structure and

this improvement is carried forward consistently through *S. robusta* (Vas.) Scribn. (Fig. 4), *S. occidentalis* Thurb. (Fig. 5), *S. avenacea* L. (Fig. 6), and *S. tweedyi* Scribn. (Fig. 7). In *Stipa comata* T. & R. (Fig. 9) we note a decided increase in size together with a certain degree of flexuousness which is such a prominent characteristic of the last two members of the series. Figure 9 is the fruit of the well-known porcupine-grass, *Stipa spartea* Trin. Every detail of the various parts has been perfected until one has a fruit which can literally bore its way into the sand as well as into the wool and skin of some unfortunate sheep. The neck of the awn is prominently twisted and very hygroscopic, the point is very sharp, and the hairs on the body of the fruit act retrorsely in their resistance to a backward action when the point is once started into the ground. The tail of the awn stands out at right angles to the arm and both wind and moisture cause a twisting motion. I have seen such fruits penetrating 2 or 3 inches into the sand and the awn circumscribing a perfect circle around the center. Commonly such an action does not take place since there is an abscission between the awn and the body of the lemma so that the awn is readily detached. It is also self-evident that in the same plot of prairie with the porcupine-grass other grasses succeed in being planted just as frequently, if not more so, even if they have no such wonderful equipment, in fact have no "special adaptation" whatever. *Stipa neomexicana* (Thurb.) Scribn. (Fig. 10) has added two interesting characteristics, namely flexuousness of the awn and hairs, and these characters as well as all the rest come to full fruition in the last species given, *Stipa pennata* L. (Fig. 11). This is truly a vegetable feather and can be used with as much effect as the highly prized aegret. The length of the awn is truly remarkable, often measuring over a foot. The structure is most beautiful and delicate. The other structures of the fruit are much like in the porcupine-grass. Now compare Fig. 1 with Fig. 11 and we see a most remarkable orthogenetic movement which has resulted in a structure which can certainly be of no use to the plant unless we follow the faith of the credulous selectionist and say that this remarkable device was especially evolved or created to attract monkeys and men by tempting them to use the fruits as ornaments and thus insuring distribution. But humor aside, the orthogenetic movement must have about expended itself. It does not seem possible to carry the progression much farther.

3. ORTHOGENETIC SERIES IN THE DEVELOPMENT OF THE HORN IN THE CORONA-HOODS OF MILKWEEDS.

(See Plate II).

The andrecium of the Asclepidaceæ is provided with a peculiar 5-lobed crown or corona. The corona-hoods are perfectly plain on the inner side, in the lower genera, like Acerates. Two species are represented in the drawings. Figure 1 represents the corona-hood of *Acerates viridiflora* (Raf.) Eat. It has two minute auricles at the sides near the base, thus really making the hood three-lobed. Figure 2 is the hood of *Acerates angustifolia* (Nutt.) Dec. The hood is three-toothed at the end, the acute middle tooth being merely a projection of the thickened midvein. In figure 3, which represents a corona-hood of *Asclepiadora viridis* (Walt.) Gr., a new structure is in evidence. The front side of the hood is cut off in order to expose the little crest or horn, since it does not project beyond the edges of the walls of the hood. This is a structure which has no antecedent. It is a new mutation and certainly has no utility to the apparatus in which it occurs. But a new process has been initiated in the system which may now progress until it evolves to a very prominent structural part of the milkweed flower. In the pleurisy-root, *Asclepias tuberosa* L. (Fig. 4), the horn has elongated greatly but is still nearly straight, while in *Asclepias sullivantii* Engelm. (Fig. 5) the horn is greatly enlarged and decidedly curved, the point projecting over the top of the stigma. A very extreme condition is attained in the horn of the hood of *Asclepias verticillata* L. (Fig. 6). The horn is about twice as long as the corona-hood and curves inward over the top of the stigma. Thus we see that in such a minute and useless structure as this little horn, the principle of progressive advancement and perfection is just as much in evidence as when the evolutionary change involves some important organ of the plant. All the milkweeds can be arranged in reference to the degree of evolution of this little corona horn. The whole series represents a succession of greater attainments until the limit is reached in the extreme species where the flower is decked out with this perfected device which has been supposed to aid in pollination but which plainly can have no such utility since Asclepiodora is really more successfully pollinated than the higher species of Asclepias. The whole series has survived and is successful

today; so it would be ridiculous to asumes an eliminative utilitarian cause to account for its origin and progression toward perfection.

4. A SIMPLE ORTHOGENETIC SERIES LEADING TO OVER-ADAPTATION.

(See Plate III).

We have all heard of how the giraffe got his long neck. The present series deals with the evolution of a "neck" at the upper end of an achene. There are a number of quite similar, independent evolutionary series in the Chicory family. The higher Compositales have very commonly developed a capillary pappus which takes the place of the vanished calyx. This pappus is, of course, epigynous in the composites while quite similar although hypogynous, capillary pappuses are developed in some of the Cyperaceæ. The ovulary of the composites is devoloped from the cortical layer of the flower bud and is not the ovulary of the carpels. The carpels are extremely vestigial and give rise only to the stigmas, style, and top of the ovulary. The neck at the top of the developing ovulary is thus a modified, cauline, cortical structure.

In *Sonchus oleraceus* L. (Fig. 1) the achene is normal, no lengthening factor being in evidence at the top. The pappus spreads out around the upper end and makes a very effective device for wind distribution. Our common species of sow-thistle are very successful weeds. When we take one step over to the genus Lactuca or lettuce a disturbance becomes evident as is shown in *Lactuca villosa* Jacq. (Fig. 2). A distinct elongation is present just below the pappus. Now this neck does not give the achene any special carrying advantages when compared with the Sonchus fruit because the neck is still too short and insignificant. Yet a mutative potentiality is indicated which, as the sequel will show, ends in a truly marvelous development. *Lactuca sagittifolia* Ell. (Fig. 3) has evolved a neck several times as long and is thus in the first stages of the production of an effective parachute. The neck is still considerably shorter than the body of the achene. In *Lactuca hirsuta* Muhl. (Fig. 4) the neck is about as long as the body of the achene, while in the highly evolved prickly lettuce, *Lactuca virosa* L. (Fig. 5) it is about twice as long. All the species of Lactuca arrange themselves in a close, orthogenetic series in respect to the neck

character. The prickly lettuce fruit is an ideal parachute and the seed is carried on downy wings of ease in the most exquisite fashion. But these plants have by no means reached the limit of progressive evolution either in respect to the structure under consideration or in various other important potentialities. Going a little father up the scale we meet a near relative of the lettuce, our common dandelion, *Leontodon taraxacum* L. (Fig. 6). Comparing the fruit of the dandelion with that of the prickly lettuce, we see that the latter is only a crude amateur in the production of an ideal parachute. The neck is now three to four times as long as the body of the achene which is ornamented by projecting prongs in a very pleasing manner. This ornamentation is already slightly in evidence in the achenes of Sonchus and Lactuca, for they are also comparatively highly evolved organisms and ornamentation is characteristic of high or extreme developments in very many lines of plants as well as animals.

We have all played at blowing the dandelion fruits from their disk and watched the parachutes sail away like a man gliding from a balloon in a man-made parachute. Now this perfected device is of no use to the dandelion. I am convinced that if it were no better than the one possessed by the sow-thistle my front lawn would still be well seeded from my next-door neighbor's crop or from the abundant dandelion community in a pasture several miles away to windward. In my back yard I have sow-thistles without the long neck on the achene and it keeps me busy at attempted eradication, just as the dandelion does in the front yard, and 20 years of effort have not succeeded in making my garden a desert in respect to Sonchus. In the dandelion we have a plain case of over-adaptation. The seed-carrying device is enormously more perfect than required for the safety and survival of the race. The dandelion has this structure not because it is of any life and death advantage to the individual but because it is one of the progressive stages in the orthogenetic development. Now one would think that nothing further would evolve. But evolution is commonly perfective in its main lines and when we study the dandelion fruit we see that a few perfective processes have not yet made their appearance. Following out another phylogenetic line of the Cichoriaceæ, which in itself would show the same interesting orthogenetic movement as the Lactuca series, we come to the last step which will be con-

sidered. In *Tragopogon porrifolius* L. (Fig. 7), the salsify of the garden, the neck is about as long as in the dandelion, being two to three times as long as the body of the achene. These long necks of the dandelion and salisfy apparently have about reached the limit. The rays of the parachute radiate out stiffly and from their sides long webby-plumose branches extend, interlocking with those from the next ray and thus weaving an ideal filmy canvass for the plane of the parachute. After the seed has been transported, the rays of the parachute are detached from the top of the neck by means of an abscission layer so the achene is not hindered in its descent into the earth. What more would you want? We have here the ideal of perfection. Now run through the series from Sonchus to Tragopogon and we see an orthogenetic evolutionary series moving persistently toward the extreme. And the entire evolutionary sequence was of no importance to the individual in its struggle against the adversities of its environment. Every one of the series would have been completely successful in its distributional and migratory requirements if the achene had never evolved a neck at all but had remained in the more simple state represented by Sonchus. Even a pappus would not be necessary. *Chrysanthemum leucanthemum* L. has no pappus whatever and no one would have the audacity to say that the oxeye daisy has any trouble in getting about in the world. You might just as well argue about the advantage or disadvantage of the green color to a green crystal, or about the advantage that a crystal may have in being 14-sided instead of 6-sided.

5. AN ORTHOGENETIC SERIES RESULTING IN A DECIDED FLATTENING OF THE VEGETATIVE SYSTEM.

(See Plate IV).

In Plate IV is given a series of diagrams to show the evolutionary progression from a radially three spiral system to a flat bilateral system. The lower Liliales, like other lower Monocotylæ, are plants with a three-spiral, radial symmetry and this condition is carried through to the lower, epigynous Iridales. Figure 1 represents a diagramatic transverse section of the stem and leaves of *Manfreda virginica* (L.) Salisb. belonging to the Amaryllidaceæ. The stem is cylindrical and the leaves are placed in the normal, radial positions. The reaction

system developing the centers of activity for the production of lateral organs dances a three-step. In other words, the property of correlation of dependent interaction extends but a third of the way around the stem bud. This as stated is the universal, primitive, monocotyl condition. In *Hymenocallis occidentalis* (Le C.) Kunth (Fig. 2) the reaction system is changed to a two-step, giving rise to a stem with two-ranked leaves. The centers of activity, developing the lateral appendages, are now 180° apart which shows that the correlation influence of the system has advanced considerably over the previous condition, so that the unitary reaction of the cells takes in a greater area or mass of cells than in the lower three-spiral system. This condition has evolved independently any number of times in the monocotyl series. It even appears occasionally as a temporary condition of bud-sporting, only to disappear again, as in the case of a Screw-palm (Pandanus) which suddenly changed from the normal three-spiral to a perfect two-ranked form and grew that way for five years when it again passed back suddenly to the three-spiral condition.

Figure 3 represents a projection of the stem and leaves of *Nemastylis acuta* (Bart.) Herb. of the Iridaceæ. Here we see the beginning of the flattening process. The stem is still cylindrical but the leaf blades show a peculiar vertical folding. *Iris germanica* L. (Fig. 4), the common iris or fleur-de-lis, shows a decided evolutionary progress in the flattening potentiality. The stem is considerably flattened; the leaf sheaths are keeled or equitant, and the leaf blades are completely flattened vertically. Figure 5 represents the condition developed in *Olsynium douglasii* (Dietr.) Bickn., a close relative of Sisyrinchium. The stem is much more flattened than in Iris. In *Sisyrinchium hastile* Bicken. (Fig. 6) the stem is flattened and has two prominent ridges on the two edges. The leaf sheaths and blades are becoming very narrow and thin. In *Sisyrinchium campestre* Bickn. (Fig. 7) the two ridges have expanded into two broad wings and in *Sisyrinchium graminoides* Bickn. (Fig. 8) the wing development has proceeded to the extreme extent. Thus the evolutionary movement has brought out a flat plant. The advance shows a movement step by step to the ultimate limit and has finally produced a plant that is ideal for the botanist to put into his plant press, when he is intent on preparing specimens for his *hortus siccus;* for which plants reduced to practically two dimensions are very appro-

priate. What more could you ask? The vegetative part of the plant is as flat as a pancake. Something has evolved in the plants that tends to throw the entire system to extreme flatness. Of what use is this to the plant? Why it is of no use. The plants which never passed one step from the primitive radial symmetry grow side by side with the blue eyed grass just as abundantly or even more so. If you must have a self-evident immediate use for this remarkable development, you will find it, as intimated above, by putting a specimen of this kind in your plant press. Your troubles in trying to reduce contrary plants to two dimensions will largely have vanished.

All of these studies again show that evolution does not proceed along utilitarian lines but that it is an intrinsic, kinetic process which is progressive, orthogenetic, and perfective in its results, the end product of the series often being a decided detriment to the convenience of the individual or, on the other hand, often a decided utility, developed enormously beyond the most extreme demands necessary for the successful perpetuation of the race. If we ask the question as to whether the plants which have taken the first steps in the progressive series will ever take any more and finally evolve to the ultimate possibility of the orthogenetic series, we have no evidence for an answer outside of the fragmentary answer of paleontology. In paleontology the evidence points mainly to the conclusion that there will be *no further change in the species as a whole* but it is possible that any individual in any of the species may take further steps in advance until the determinate limit of the series is attained. But such individuals are the first of new species and the old species continues to reproduce itself unchanged according to its hereditary constitution until it is eliminated through adverse conditions.

EXPLANATION OF PLATE I.

Progressive series in the evolution of the awn in Stipa.

Fig. 1. *Stipa macounii* Scribn.
Fig. 2. *S. scribneri* Vas.
Fig. 3. *S. viridula* Trin.
Fig. 4. *S. robusta* (Vas.) Scribn.
Fig. 5. *S. occidentalis* Thurb.
Fig. 6. *S. avenacea* L.
Fig. 7. *S. tweedyi* Scribn.
Fig. 8. *S. comata* T. & R.
Fig. 9. *S. spartea* Trin.
Fig. 10. *S. neomexicana* (Thurb.) Scribn.
Fig. 11. *S. pennata* L.

All reduced on the same scale to one-half natural size.

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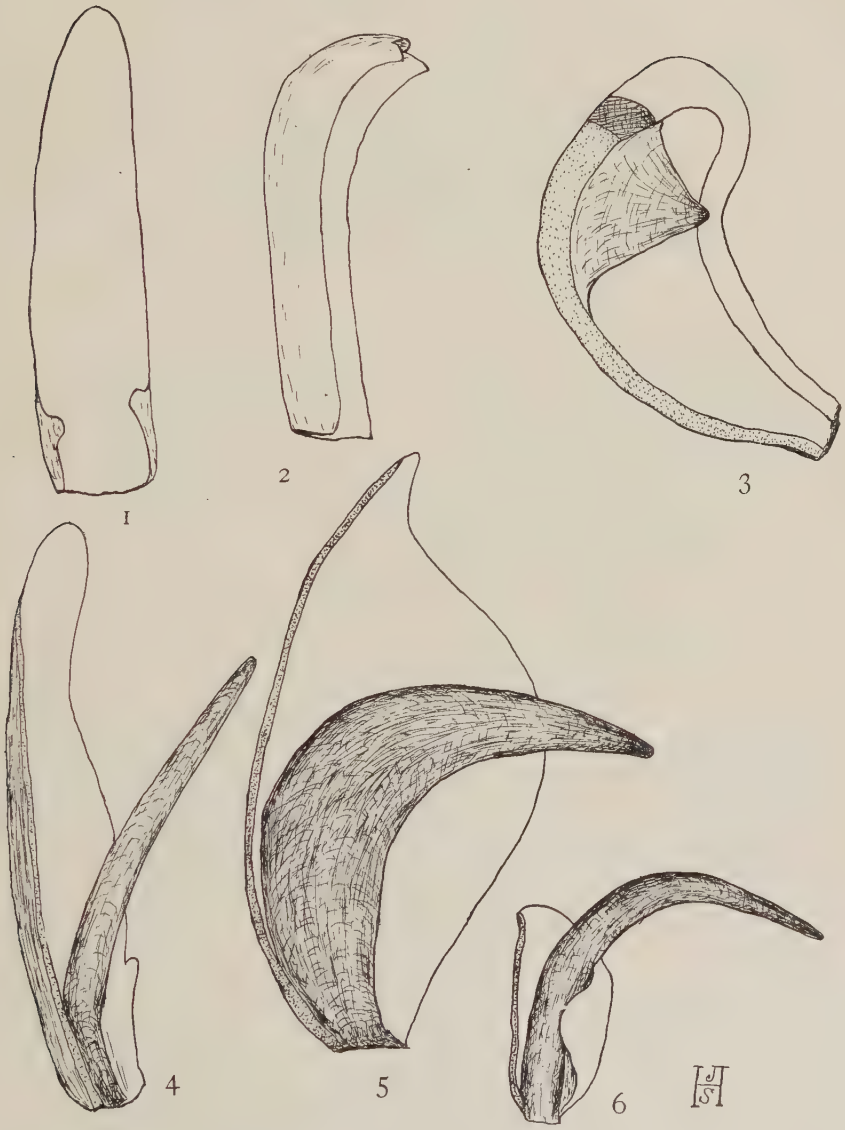
EXPLANATION OF PLATE II.

Evolution of the horn in the stamen appendage of species of milkweed.

Fig. 1. *Acerates viridiflora* (Raf.) Eat.
Fig. 2. *Acerates angustifolia* (Nutt.) Dec.
Fig. 3. *Asclepiadora viridis* (Walt.) Gr.
Fig. 4. *Asclepias tuberosa* L.
Fig. 5. *Asclepias sullivantii* Engelm.
Fig. 6. *Asclepias verticillata* L.

All magnified on the same scale about 6 diameters.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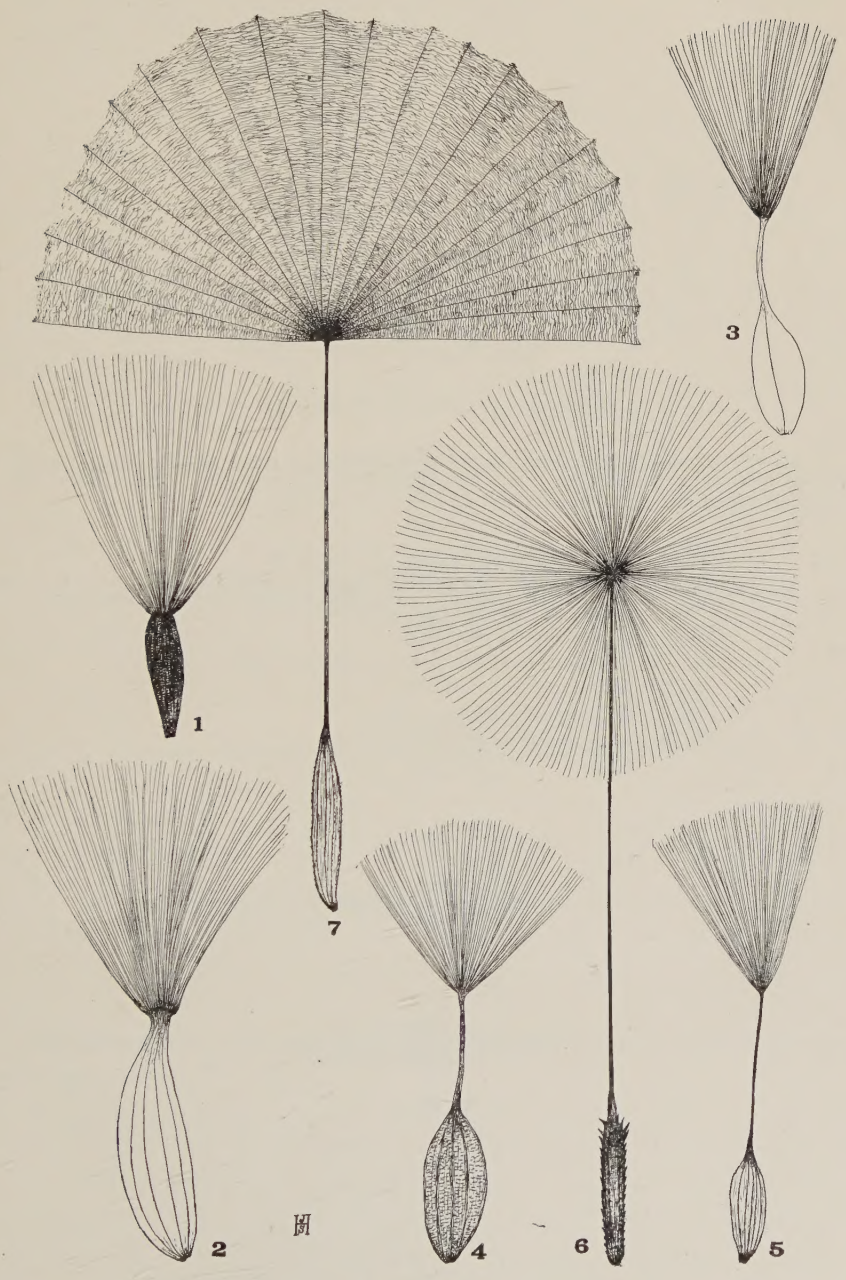
EXPLANATION OF PLATE III.

Orthogenetic series in the evolution of an elongated neck between the body of the achene and the pappus in the chicory family.

Fig. 1. *Sonchus oleraceus* L.
Fig. 2. *Lactuca villosa* Jacq.
Fig. 3. *L. sagittifolia* Ell.
Fig. 4. *L. hirsuta* Muhl.
Fig. 5. *L. virosa* L.
Fig. 6. *Leontodon taraxacum* L.
Fig. 7. *Tragopogon porrifolius* L.

All Figures magnified about 4 diameters except Fig. 7, which is magnified about 2 diameters.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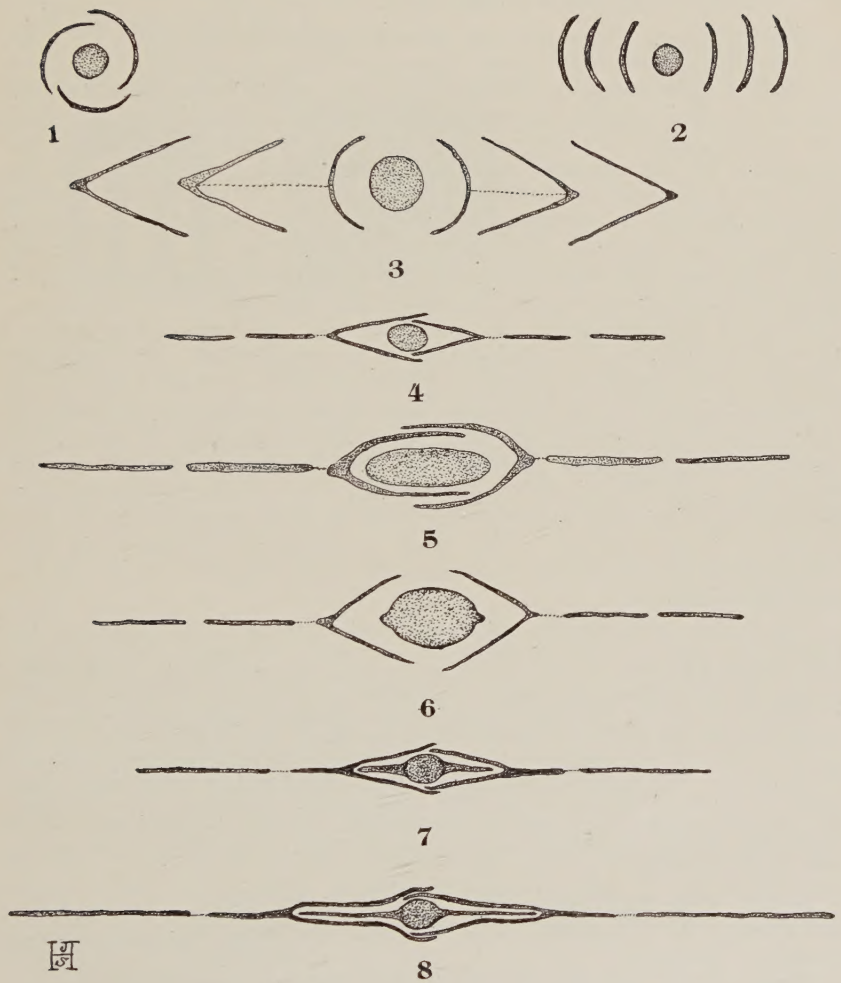
EXPLANATION OF PLATE IV.

An orthogenetic series from the Iridales showing a remarkable change from a radially three-spiral system to a flattened bilateral system. The figures are profile projections or cross-sections of the stem and leaves.

Fig. 1. *Manfreda virginica* (L.) Salisb. × ½.
Fig. 2. *Hymenocallis occidentalis* (Le C.) Kunth. × ½.
Fig. 3. *Nemastylis acuta* (Bart.) Herb. × 2½.
Fig. 4. *Iris germanica* L. × ½.
Fig. 5. *Olsynium douglasii* (Dietr.) Bickn. × 8.
Fig. 6. *Sisyrinchium hastile* Bickn. × 8.
Fig. 7. *S. campestre* Bickn. × 8.
Fig. 8. *S. graminoides* Bickn. × 8.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BOOK NOTICE.

INSECTS, TICKS, MITES AND VENOMOUS ANIMALS OF MEDICAL AND VETERINARY IMPORTANCE. By W. S. Patton and Alwen M. Evans.

This work of 785 pages and numerous illustrations must be considered a successor to the very comprehensive and valuable *Text Book of Medical Entomology*, by Patton and Cragg, which is now out of print. The new book is adapted especially for class use and consists of exercises for twenty-eight lectures and laboratory periods with elaborate discussion of the material used for demonstration and reference to methods of preparation for the different species. It is especially full in descriptions and is admirably illustrated with figures of the morphological details concerned with the attacks of the species on their hosts and those used in identification. There is also considerable detail concerning life history and habits and some discussion of control measures. Other parts to be devoted to (2) "public health," (3) "tropical hygiene," and (4) "veterinary," are announced as in preparation. For students outside of the School of Tropical Medicine there may be a feeling of disappointment that no bibliographical references are given to works which are mentioned or which must naturally be consulted by a student of medical entomology. Possibly for the isolated student it would have been preferable to give some of this, even at the expense of less detail concerning specimens that are used as demonstrations under the direction of the authors. The book is available directly from the authors and the following announcement from Dr. Patton should be carefully noted:

"As it is the only practical book on the subject, the writer is strongly of the opinion that its price should be within the reach of all to whom it may be of use. Had it been published in the usual way its price would have been prohibitive to most medical officers and nearly all students of entomology. Under the circumstances it can only be obtained from the Entomological Department, Liverpool School of Tropical Medicine, and would-be purchasers will therefore only waste time by applying to booksellers, who will themselves have to obtain it from the above source. Any number of copies can be sent, and it will be just as easy, if not easier, to obtain it in this way as from a bookseller. The price, 20/–, includes packing and postage to any part of the world. All copies going to the United States will contain an invoice for Customs purposes. The duty will bring the price to about $5.00."

Apply with remittance (20/–) to Miss M. Brown, Department Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool, England.

The book is a fine example of technical work and beautifully printed. It will certainly be warmly welcomed by students of medical entomology.

Herbert Osborn.